“Mapping Pulmonary Tuberculosis in Khartoum State Using Geographic Information Systems (GIS)”

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Dedication

To the memory of my father, Ibrahim, who spent his life in teaching and remedying people.

To My beloved Mother, Batoul, for all the sacrifices and believe in us.

To My wonderful wife, Manal, You are everything for me, without your love and understanding I would not be able to make it.

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To all my sisters and brothers who prayed for me to succeed,,,

Abstract

Mapping Pulmonary Tuberculosis in Khartoum State Using Geographic Information Systems (GIS)

Background: Sudan shoulders the second highest TB burden in WHO-EMRO (Eastern Mediterranean Region). Khartoum state, where this study was conducted, has the highest number of notified TB cases in comparison to other states, with recorded 7,570 and 6,585 case notifications in the years 2007 and 2008 respectively. Mapping PTB cases geographically, using Geographic Information Systems (GIS) to identify geographical areas with on-going TB transmission and exploring various risk factors contributing to this transmission will be of paramount importance in taking effective control measures to combat the emergence and re-emergence of TB in Sudan. **Objectives:** To map the geographical distribution of PTB cases in Khartoum state over a two years period between 2007-2008 using GIS and to observe variations in population density, disease incidence, and prevalence of PTB. **Design:** a cross-sectional retrospective, illustrative and descriptive study**. Settings:** 36 Administrative units and 33 TBMUs in Khartoum State**. Population:** 6182 PTB patients. **Software and devices:** ArcGIS 9.3.1 and GPS (Garmin 60CSx)**. Findings:** We successfully mapped the geographical distribution of PTB in large area covering the Khartoum state and found that distribution of PTB cases were attributable to several characteristics of the sociopolitical and socio-economical realities of Khartoum State. PTB cases were concentrated in AUs with areas of poverty, settlement areas of IDPs and poor urban migrants. **Conclusions:** GIS is a promising technology to study the distribution of infectious diseases in settings like Khartoum where unavailability of systematic population records may partly be overcome by mapping technologies such as Google maps. Pertinent limitations and implications of the GIS use have been elaborated in the thesis.

Keywords: Pulmonary Tuberculosis, Geographical information systems, Google maps, infectious disease epidemiology, ArcGIS

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List of Acronyms

ARI	Annual Risk of Infection
AUs	Administrative Units
CBS	Central Bureau of Statistics
CDC	United States ,Center of Disease Control
CDR	Case Detection Rate
CFR	Case Fatality Rate
CHWs	Community Health Workers
DALYs	Disability Adjusted Life Years
DOTS	Direct Observed Therapy
DR	Drug resistant
Epi-lab	Epidemiological Laboratory (NGO)
EPTB	Extra Pulmonary Tuberculosis
FMOH	Federal Ministry of Health
GIS	Geographic Information Systems
GPS	Global Positioning System
HIS	Health Information System
HIV	Human Immuno-deficiency Virus
ICT	Information Communication Technology
IDPs	Internally Displaced Peoples
IS	Information System
IUALTD	International Union Against Tuberculosis and Lung Disease

LHL	Norwegian Heart and Lung Association
M&E	Monitoring and evaluation
MDR-TB	Multidrug resistant TB
MOTT	*Mycobacterium Other than tuberculosis*
MTB	*Mycobacterium tuberculosis*
NGOs	Non Governmental Organizations
NTP	National Tuberculosis Control Programme
PAUs	Population administrative units
PHCU	Primary Health Care Unit
PTB	Pulmonary tuberculosis
SMOH	State Ministry of Health
TB	Tuberculosis
TBCNR	Tuberculosis Case Notification Rate
TBMUS	Tuberculosis Treatment Units
TBR	Tuberculosis Register Book
TBTC	Tuberculosis Treatment Card
VL	Visceral *leishmaniaisis*
WHO-EMRO	World Health Organization, Eastern Mediterranean Region

CHAPTER1. INTRODUCTION

1.1 Background of the Study

Tuberculosis (TB) is an air-borne infectious disease caused by bacillus *Mycobacterium tuberculosis (MTB)* that is spread through droplets from infectious TB patients(1). According to the World Health Organization (WHO), TB is ranked as the seventh leading cause of morbidity. The WHO estimates that more than 2 billion persons are infected with MTB and that more than 2 million die of the disease each year. More men than women are diagnosed with TB and die of it, and the global Disability Adjusted Life Years (DALYs) for TB has been calculated to be 2.5%. At the same time, TB is a leading infectious cause of death among women. Approximately 700,000 women die of TB each year and more than 3 million become sick with TB yearly. This accounts for 17 million DALYs (2). Poverty, malnutrition, aging, and Human Immuno-deficiency Virus (HIV) are the most powerful risk factors for the progression from infection to disease (2).

Drug resistance (DR) and the HIV pandemic are considerable threats to TB control measures and multidrug resistant TB (MDR-TB) poses a serious threat to public health through the transmission of MTB that does not respond to first line anti-TB drugs and results in immeasurable morbidity and mortality of tuberculosis(3).

TB represents a great public health threat for those who live in tropical and subtropical regions of the world and is responsible for limiting individual productivity and socioeconomic development(4).

Sudan shoulders the second highest TB burden in WHO-EMRO (Eastern Mediterranean Region) and Case Detection Rate (CDR) for the year 2008 was 32.3%. Even this figure is unlikely to reflect the magnitude of TB cases in the country because CDR has been found to be a poor measure of TB cases (5). In Sudan, new sputum smear positive cases of TB were stabilized over the last four to five years. TB notification rate was 33/100,000. The annual risk of infection (ARI) is 1.8 with 29,967 new sputum smear positive cases estimated annually. TB incidence rate is 107/100,000 and HIV prevalence is 7 %(2).

Khartoum state, where this study was conducted, has the highest number of notified TB cases in comparison to other states. Total cases of all types reported in 2007 and 2008 are 7,570 and

6,585 respectively. Extra-pulmonary TB (EPTB) were 1267 (17%) in 2007 and 1007 (15%) in 2008. CDR was 69 %(2007) and 55 %(2008) and success rate of 81% for 2007 and 76% for 2008(6).

In Sudan, the National Tuberculosis Control Programme (NTP) was established in 1974 and regular monitoring of case-finding and treatment, as well as adoption of the WHO's policy package for TB control (directly-observed treatment (DOTS)) started in 1993. From 1993 and up to now, regular technical support to the NTP has been provided by the Norwegian Heart and Lung Association (LHL), the International Union Against Tuberculosis and Lung Disease (IUALTD), and the WHO(7).

Sudan has a well-performing NTP, which manages to implement and expand DOTS as the most cost-effective strategy throughout the country. Sudan's NTP reached its full expansion in 2002 with 300 TB Management Units (TBMUs) and 903 DOTS centers. Nevertheless, several gaps and challenges face the Programme and hamper the implementation of DOTS strategy in efficient ways. The result of such is that the Programme has not achieved the required global targets. These gaps and challenges result in suboptimal management of TB suspects and under-reporting of cases from both non-NTP providers and DOTS units within the NTP. Furthermore, because HIV testing is not regularly available to TB patients, routine NTP reporting of treatment outcomes provides an overall Case Fatality Rate (CFR) without a breakdown by HIV status. The lack of HIV testing also results in inadequate management of TB/HIV co-infected cases. And, additionally, failure to completely and timely treat considerable numbers of newly diagnosed TB patients increases the number of re-treatment cases (failure, relapses, returns after default) and chronic cases. Such a situation ultimately facilitates the emergence of MDR and poses a real threat to TB control measures (8).

The purpose of Health Information System (HIS) is to improve health care delivery through effective planning, management and evaluation (M&E). However, there is still no effective NTP Information System (IS) to support the process of planning, management and evaluation. In Sudan HIS is fragmented and tends to based on vertical programmes (e.g. TB, HIV/AIDS, Malaria control Programmes, etc). Unfortunately, each programme has its own IS that is rarely coordinated with other Programmes(9) . Within Sudan's NTP, the collected data are aggregate in papers from different TBMUs at the locality level. This data is often irrelevant, of poor quality, and not linked to a referenced population (10). This data is compiled at the state level and then sent to the national NTP as aggregate by TBMUs. But, when compared with data in the central unit's reporting system, a large discrepancy was observed, thus rendering it of poor quality and limiting its use for comprehensive analysis and further evidence-based decision making for effective programme management (10).

Thus, it is important to reform the available IS and make use of Information Computer Technology (ICT) that leads to the introduction of computers and the development of computer-based information systems that can lead to better management, monitoring , analysis and evidence-based decision making to improve the programme quality indicators. Geographic Information Systems (GIS) is an ICT that is currently increasing in importance and visibility. It is suggested that over ninety percent of health issues have a spatial component that is clearly related to human activities and factors causing diseases. Concentration of a disease in special areas statistically indicates the presence of factors that cause this disease. Moreover, the co-existence of such factors in a specific area increases the probability of dramatically increased occurrence of the disease. For this reason, GIS is a suitable tool to study and compare the spatial distribution and pattern of both factors and diseases (11).

Application of GIS in health includes (12):

- Analyses of spatial patterns of health care access
- Epidemiology and surveillance
- Monitoring of diseases and planning of interventions
- Geographical correlations of health outcomes
- Visualization and exploratory analysis of epidemiological data
- Environmental and social determinants of human risk to diseases
- Planning and management
- Complex analysis and research
- Advocacy, communication and social mobilization.

The World Health Organization describes how GIS is useful in public health Programmes:
"GIS provide ideal platforms for the convergence of disease-specific information and their analysis in relation to population settlements, social, health services and the natural environment,

highly suitable for analysis of epidemiological data and finding trends and interrelationships that would be difficult to reveal in tabular format. GIS allows policy makers to easily visualize problems that related to health and social services and natural environment and accordingly to effectively target resources" (13).

NTP programmes could use GIS in many ways to strengthen their programmes by mapping the following:

- geographical distribution of different forms of TB, TB hotspots,
- distribution of resources (facilities, health personnel, equipment such as microscopes),
- trends over time,
- TB treatment success and failure rates in relation to variables such as remoteness (accessibility),
- TB drugs availability, and
- Socio-economic and environmental factors contributing to TB infection (12).

Other tools that can be used for mapping are Healthmapper and EpiMap. Healthmapper was developed by the WHO and includes a database of core baseline geographic, demographic and health information. This information includes locations of communities and their health care and education facilities as well as details about natural and environmental features like administrative and health boundaries, elevation, and the transportation network. However, detailed data is not available for every country. A secondary tool used for mapping is EpiMap (part of EpiInfo), designed by the United States Center for Disease Control (CDC) for use by public health practitioners and researchers. The programme can be used for data entry and analysis with epidemiologic statistics, maps and graphs. Both programmes are user-friendly and available free of cost. However each one has its limitations.

1.2 Problem Statement and Research questions

The transmission of TB is traditionally understood to happen at home and due to exposure to an infectious TB case. However, recent studies using restriction fragment length polymorphism indicate that transmission is not limited to prolonged and intense contact at home, but can also occur in different places of social gathering, such as prisons, schools, homeless shelters, churches, bars and flights (14). In Khartoum state, and mostly in the tripartite metropolitan with a population about 5 million and more than 1.7 million internally displaced peoples (IDPs) distributed across three towns, understanding the transmission pathways and clustering of pulmonary TB (PTB) using Geographic Information Systems (GIS), will increase knowledge about the dynamics of TB through spatial visualization of PTB distribution and will discover patterns of geographic association (clusters or hot spots) for transmission (14;15). In epidemiological research relating to TB, much remains to be understood about the transmission dynamics in developing countries and no such study has been conducted in Sudan. Thus, to map PTB cases geographically, using GIS to identify geographical areas with on-going TB transmission and exploring various risk factors contributing to this transmission will be of paramount importance in taking effective control measures to combat the emergence and re-emergence of TB in Sudan. The aim of this research is thus to answer the following questions based on the above problem statement:

1. What is the geographic distribution and spatial relation of reported TB cases to the population density?
2. What are the differences of TB classification and treatment outcome indicators for the spatially mapped TB cases in the 36 AUs of Khartoum state?

1.3 Research Objectives

- General:
    - To map the geographical distribution of PTB cases in Khartoum state over a two years period, 2007-2008, using GIS to guide the NTP Programme to improve TB services.
- Specific:
    - To create thematic maps to enable visualization of variations in population density, disease incidence, and prevalence, thereby indentifying areas and subpopulations at increased risk of TB.
    - To examine and analyze the relationship between PTB and socio-economic, environmental factors and any relevant information in Khartoum state.

1.4 Research Settings and Context

The context of this study is Sudan, the largest country in Africa with a total area of 2,505,810 sq km, extending between 15° North latitude and 30°East longitude and located in Northeastern

Africa, and bordering Egypt to the North, the Red Sea to the Northeast, Eritrea and Ethiopia to the East, Chad to the West, Libya to the Northwest, the Central African Republic to the Southwest, and Kenya, Uganda, and the Democratic Republic of Congo to the South (Fig.1& Fig.2). The total population is 39.2 million (2008 census). Of them, 29.8% are urban, 63.2% rural, and 7% nomads with 4.9 million IDPs .The overall population density for the country is 17.4 persons per square kilometer of land area.

Administratively, Sudan is divided into 25 states and 210 localities. Each locality is subdivided into administrative units.

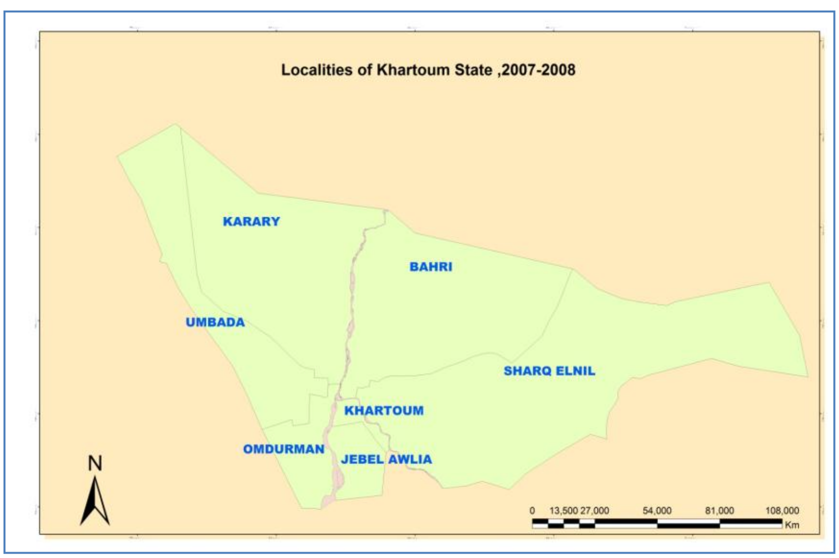
Figure: 1 Location of Sudan within Africa

Figure: 2 Sudan boundaries and administrative regions (states)

Khartoum, where the study was conducted (Fig.3) is one of the 25 Sudan states. It has an area of 22,122 square kilometers, extending between 34.45° East longitude and 16.45° North latitude, bordering Gazira and White Nile states to the south, Kassala and Gadarif states to the east, River Nile state to the North and North Kordofan state to the West. Is has a total population of 5.2 million (2008 census). Khartoum state is the national capital of Sudan. The state represents almost all ethnic groups of the country and is administratively divided into seven localities (Khartoum, Jabel Awliya, Sharg Alneel,Bahri, Oum Durman, Karrari and Oum Bada) (Fig.4), 36 administrative units (AUs), and 19 health areas.

Figure 3: Khartoum State in relations to other states

Figure 4: localities of Khartoum state



Health services structure in Khartoum state are decentralized and composed of three levels: state, locality, and health unit. There are 43 public hospitals, 147 health centers, 235 dispensaries, 365 primary health care units (PHCU), and 185 NGOs centers (16). Children with underweight are 3.7%, stunting 11.7, wasting 1.8%, and under-five Vit.A supplementation 92.5%. TB immunization coverage is 94.6% (fully immunized children 66.8%), the percentage of household who use solid fuels (wood, charcoal, crop residues and dung) is 21.8% , knowledge of two means of preventing HIV transmission amongst women aged 15-49 years is 15.8%, and percentage of food insecurity is 4.2%(17).

In table (1) below are the main indicators for the state according to the 5th population and household census conducted in 2008.

Table 1: Main Summary Indicators

No	Indicators	Value
1	Percentage of Population under Age 15 years	35
2	Dependency Ratio	61.5
3	Sex Ratio	110.9
4	Crude Birth Rate	24.4
5	General Fertility Rate	101.5
6	Total Fertility Rate	4.3
7	Infant Mortality Rate	75
8	Child Mortality Rate	91.8
9	Crude Death Rate	16.4
10	Maternal Mortality Ratio (Per 100000 live Births)	389
11	Percentage of Population with Disability	4.1
12	Percentage of Population having access to Electericity for Lighting	59.6
13	Percentage of Population having access to Electericity for cooking	0.2
14	Percentage of Population who own a vehicle	16.4
15	Literacy Rate	80.3
16	Net Migration Rate Per 1000	347.1
17	Population Growth Rate	2.7

Source: CBS, 5th Population and Household census, 2008,

1.5 Motivation

I was able to recognize the importance of using GIS after having a discussion with my supervisor, Professor Gunnar, about how using the GIS tool and mapping TB cases can help in understanding the pathways of TB infection in relation to subpopulation groups and surrounding socioeconomic and environmental factors. Additionally, having worked as an M&E officer in the NTP, with responsibility for monitoring and evaluating the programme activities, assessing the gaps and challenges hampering the implementation of effective TB control measures, and using evidence-based decisions in planning, monitoring and evaluation of the programme activities, I found myself motivated to apply GIS in mapping TB in Khartoum state - one of the most densely populated states that represents all ethnic groups of Sudan and is a target for the majority of IDPs who live in city slums, camps and squatter areas.

1.6Target Audiences

Target audiences of potential benefit from this study are as follows:

- Politicians and decision makers of health related sectors
- NTP manager and State TB coordinators
- Public health professionals involved in diseases control in Sudan
- Public health professionals managing curative and preventive medicine at national and state level.
- GIS professionals who are interested in using GIS in disease control
- Medical and public health students who are interesting in the use of GIS in disease control
- National and international organizations (NGOs) working in the field of health and disease control in Sudan and developing countries.

1.7 Aims and Expected Contributions

This study aims to increase the awareness of health professionals with regard to the use of GIS in disease control, showing health professionals, policymakers and the media that maps are excellent tools for displaying the geographic distribution of health indicators. In addition, maps can reveal inequity (Curto de Casas, 1993; Saurerborn et al., 1995b) in health care delivery and then allow for remedying of gross spatial inequities in the allocation of resources or in health outcomes (18). Audiences might be reminded of the usefulness and importance of mapping disease and outbreak by recalling the work of John Snow who, as early as 1854, demonstrated such during the cholera outbreak in London. Thematic maps have the potentiality in assisting health planners in monitoring disease control measures and interventions or allocating new health infrastructures. Finally, this study will pave the road for and prompt other professionals to conduct further research on TB and other infectious diseases using GIS technology, especially given that there are not many studies in this field and this country.

1.8 Structure of the Thesis

The thesis structured in seven chapters. Chapter one presents the background of the study and includes the problem statement and research questions, objectives of the research, and the research settings, motivation, target audiences and contributions. In chapter two, literature review and the background and geographic, socio-demographic, socio-economic and political context of Sudan is presented. Research approaches and methods are presented in chapter three. In chapter four, an overview of study findings is presented. Chapter five includes the discussion part of the thesis, followed by the conclusions and implications, which are presented in chapter six.

CHAPTER 2.LITERATURE REVIEW

2.1 Use of GIS for Studying Pulmonary Tuberculosis

TB in Sudan is increasingly concentrated in urban settings, especially in city slums and heavily-populated IDP and squatter areas, where homelessness, poor ventilation, and crowding have been associated with an increased risk of infection and transmission(1).

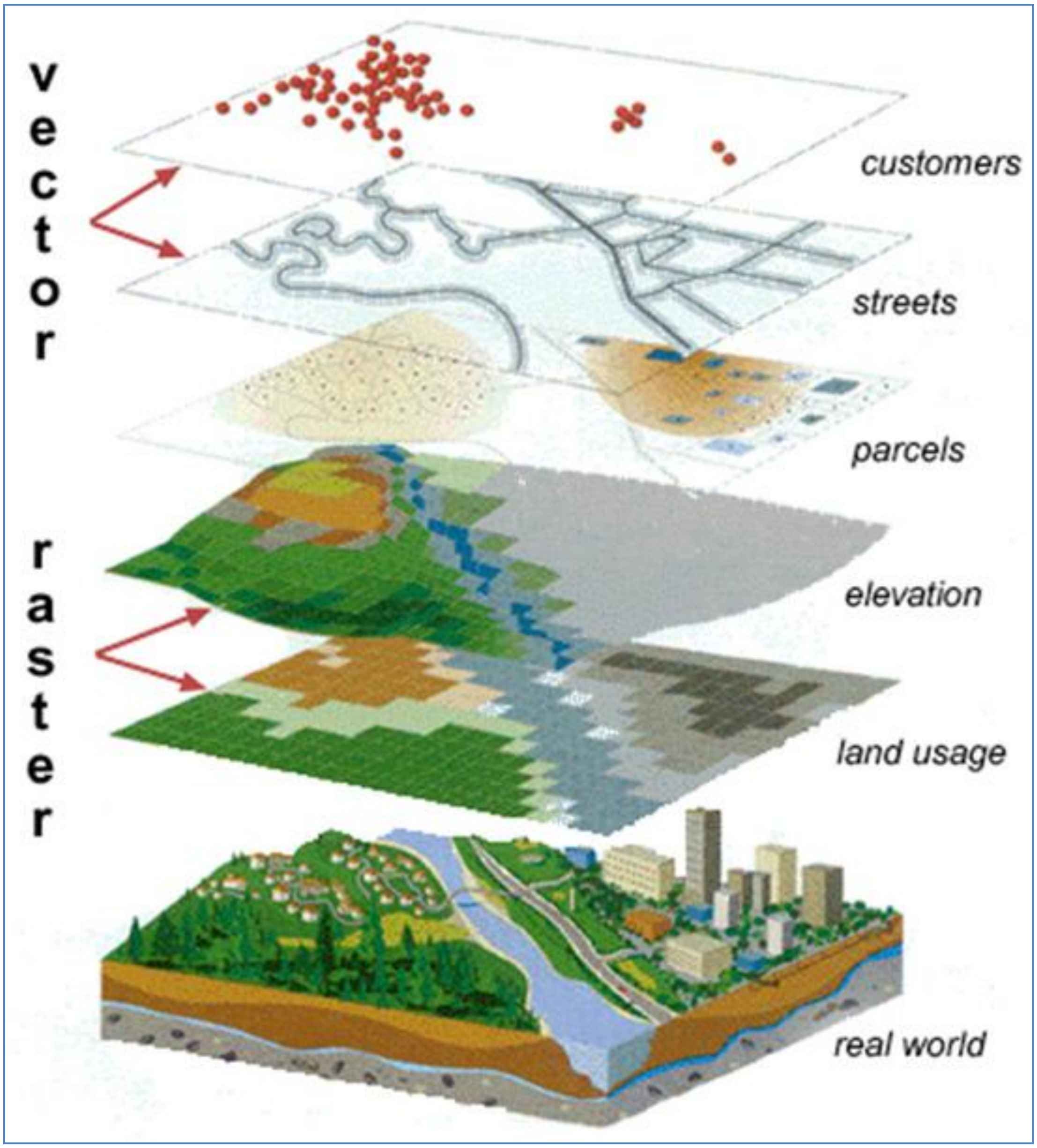
Analysis of routine TB reports in Khartoum state and during recent years has highlighted the presence of ongoing transmission in certain areas compared to others. The highest number of TB cases is reported by TBMUs located in IDP areas and city slums, demonstrating the importance of the role of space and location in TB transmission (19).

2.1.1 Geographic Information Systems

"GIS is an automated system for the capture, storage, retrieval, analysis and display of spatial data (i.e data pertaining to variables that assume different values at different locations) (Vant Beurden & de Lepper 1995; Boelaert et al.1998)" (12). All information stored in GIS is linked to geographic points or coordinates and all points are related to each other through the use of a standard coordinate system. Therefore, GIS is highly suitable for analyzing epidemiological data and revealing trends and interrelationships that would be more difficult to discover in other formats. Examples of these analyses include the detection of spatial clustering, the detection of differences over space and time, and associations between risk factors and diseases (14;15;20-24).

The presence of TB cases, TBMUs, districts, and blocks can be represented on a map to analyze their spatial relationship to each other. This allows the incorporation of proximity as a variable that may be used in reference to other cases or to particular locations or resources. Moreover, in addition to spatial data, one can add many layers of different attributes and information to these points, districts, regions or other map locations (Fig.5). Adding environmental point and socioeconomic indicators to a certain area is a good example of this process (14;20;23;25-29).

Figure 5: Demonstration of possible layers in GIS (30)



2.1.2 GIS and Infectious Diseases

GIS has been used in public health for surveillance of different infectious diseases. It has proven its usefulness in water-borne outbreaks to identify point sources of contamination. In Bangladesh a GIS-based approach was used to identify spatial risk factors like proximity to water sources (31). The indentified clusters of cholera cases in space/time and spatial proximities were found to be statistically significant and higher than would be expected in the same region in the past years.

GIS has been used to detect the environmental variable of malaria infection in Egypt governorates. The discriminate model of analysis between the governorates used was able to classify 96.3% of the risk categories and indicated that the most important predictor of risk is hydrology. Spatial analysis indicated that malaria in Fayoum governorate is associated with the presence of both efficient malaria vectors and hydrology and soil (32).

GIS has been used to study environmental variables in relation to *Visceral Leishmaniasis* (VL) in Gedaref state in the Eastern Part of Sudan. A model was developed to map the distribution and incidence of VL in 190 villages. The resulting model was able to identify that the average rainfall and the altitude were the best predictor of VL incidence (33).

GIS also has been used to detect patterns of chronic diseases like cancer and mortality due to cancer. Hsu et al., using GIS, observed geographical disparities in mortality due to breast cancer among racial groups. Yet, while geographical differences in breast cancer mortality were evident among racial groups, this study failed to demonstrate hot spot clusters or persistent spatiotemporal trends in increased mortality due to breast cancer (34;35).

2.1.3 GIS and Tuberculosis

Different approaches and methods have been implemented to geographically map TB in different countries using quantitative and/or qualitative approaches and combining them with geospatial mapping of TB using different type and versions of GIS technology. The following GIS software was used in mapping TB in different countries: ArcView/Arc GIS and various extensions produced by ESRI, MapInfo developed by MapInfo and it is commercial GIS package, EpiInfo/EpiMap developed by CDC and available for free, and healthmapper, which is a WHO/UNICEF Programme that is available free to most developing countries and provides excellent means for analysis and epidemiological data mapping to reveal trends, dependencies and their inter-relationships (36).

- **Mapping geographical distribution of TB and TB clusters/hotspots,**

  GIS and spatial analysis programmes have been used to identify risk factors for TB infection or transmission. In Cape Town, South Africa, a spatial analysis showed that TB cases were clustered around local bars (Shebeens),clinics and churches (often gatherings in confined homes), all of which were located in overcrowded and poor areas of the community(15;37).

These studies suggested that these areas of social gathering like Shebeens, clinics, churches and confined homes are responsible of transmission of TB. However, is hard to say that the spatially clustered TB cases were involved in transmission, since restriction fragment length polymorphism (RFLP) was not done for those TB patients. Despite this, the results of these studies assist in guiding public health interventions to enhance TB control efforts and identify areas that need to be further researched.

Touray K et al. have conducted spatial analysis of TB using GIS and SatScan in Greater Banjul, Gambia, to determine whether there is significant TB case clustering. It was found that there is evidence of significant clustering of TB cases in greater Banjul. The systematic use of such information by TB surveillance may guide to effective deployment and allocation of resources (20).

Randremanana R.V et al. conducted spatial cluster analysis of TB in Antananarivo, the capital of Madagascar, using GIS. Out of six districts, spatial clusters observed in 3 revealed that the change in risk of TB clusters was linked to socio-economic factors (e.g. household amount of ownership of tap water) and patient care factors (e.g. patients lost to follow-up)(24).

Neeraj Tiwari et al. conducted geo-spatial analysis to identify clusters of TB in Almora district in India using GIS. Significant high rate spatial and space-time TB clusters were identified in three areas of the district (38). These findings provide useful information on the epidemiological situation of TB in the district and therefore guided the use of evidence-based strategies for more effective TB control.

Daisuke Onozuka et al. conducted space-time scan statistics to predict TB clusters in Fukuoka, Japan. The clusters of TB cases were found in the area of Chikuho coal mining (1999, 2002, 2003, and 2004), in Kita-Kiyushu in 2001, and in the Fukuoka urban area in 2001(39). However, this study was based on the assumption of circular spatial scanning windows and space-time cylinders, and the centroid of each cluster location (i.e, administrative districts such as cities, towns and villages) is not necessarily included in the cluster circle. Actually it is impossible to include in the detected circular cluster administrative areas with complicated geographical boundaries.

- **Linking GIS with molecular surveillance and socio-economic and socio-demographic indicators**

  Moonan P.K et al. used geographic analyses among isolates molecularly characterized using IS6110-based RFLP analysis to identify identical TB cases in the Fort Worth-Dallas area in Texas. They identified 2 spatial clusters corresponding to 2 zip codes in the downtown area. This gives an example of how geographic unit impacts the interpretation of results and therefore can inform decisions about resource allocation and early detection of outbreaks or other risk factors for TB disease (40).

  Affolabi D et al. conducted a study using GIS and molecular tools to characterize a possible outbreak of the MTB Beijing strain in Cotonu, Benin (41). This study showed isolates of streptomycin resistant MTB strains in most patients who lived and worked in the same area and used the same local bars. The outcome of this study guided the NTP to take effective measures in combating TB at the individual and community level.

  Chan-Yeung M et al. conducted spatial analyses among RFLP TB cases to identify socio-demographic and geographic indicators responsible for the distribution of TB in Hong Kong using GIS. Low education attainment, old age, and poverty were significant determinants of the rate of TB in different part of Hong Kong. However, none of the socio-demographic indicators were related to TB transmission (14).

  Bishai W.R et al. conducted geographic and molecular analysis of TB cases in the city of Baltimore and concluded that residences of cases with identical MTB strains were spatially aggregated as associated with low socio-economic status and high drug use (42).

- **Analyses of spatial patterns of health care access**

  Wilkinson D et al. and Tanser F et al. have used GIS and GPS in a Hlabisa community-based TB treatment programme. These researchers plotted TB supervision points used by district health systems and quantified access by using GIS to measure the mean distance from each home in the district to the hospital, clinics, community health workers (CHWs) and volunteer supervisors. Adding clinics and then CHWs to the hospital as treatment points reduced the mean distance from home to treatment point from 29.6 km to 4.2 km and to 1.9 km respectively. Adding volunteers further decreased the distance to 800 m. This study showed that GIS/GPS effectively documents and quantifies the impact of increased accessibility to treatment after the expansion of the services from health facilities to include CHWs and volunteers (23;43;44).

- **TB risks and socio-economic level**

Vendaramin S.H.F et al. conducted a study to explore TB risk in relation to potential determinants in the city of Sao Jose do Rio Preto, Brazil using GIS. This study showed that TB risk in the city was twice high in areas of low socio-economic level than the higher ones. The outcomes of this study assisted the municipal health department to find effective interventions to minimize the risk of disease among population (45).

- **Monitor Programme Performance**

Thomas N et al. conducted study using GIS in TB control in Malawi. Incidence of TB was mapped by district and district performance was color coded and compared to the programme targets. Analysis of the maps showed that performance varied from year to year, as a district with bad performance in 1997 improved in 1998 and again worsened in 1999(46). Such information helps the NTP in Malawi to find causes and use effective interventions to rectify the problem.

2.1.4 Geographic Information Systems (GIS) in Sudan

Effective implementation of GIS technology in developing countries is still a struggle, and Sudan is no exception. In Sudan, effective implementation and utilization remains a great challenge due to many existing social, economic, political and organizational difficulties (47). ICT was introduced in Sudan in the early seventies, but, up to now, the use of GIS in health research is limited to a few studies in risk mapping of VL in eastern Sudan (33) and spatial and temporal distribution of the malaria mosquito *Anopheles arabiensis* in northern Sudan (48). There are available GIS technologies in different government authorities and ministries, but these are of limited use. Currently, some of the universities included GIS as part of their curriculum and there exist many crash courses on GIS conducted by people who received their specialty in GIS from abroad. In the last years private sectors like communication, private companies of dairy production, and water and electricity establishments also started implementing GIS technology in their business.

Yet, implementation of GIS facing many challenges (49):

1. No working relationship established between institutions dealing with GIS technology
2. Lack of financial and human resources.

3. Limited technology transfer due to barriers in the organizational and decision making process.

4. Limited communication between institution producing health data and geographic information.

5. Limited availability of basic maps.

6. High cost of available basic maps, as introduced by the monopoly of people working with GIS technology.

7. Lack of GIS skills.

8. Availability of relevant valid data for GIS.

CHAPTER3. STUDY CONTEXT OF SUDAN

3.1 Geography

Sudan expands from the harsh arid desert of the Sahara in the north, through flat lands in the central region and ends with the tropical wet and dry southwest. Natural resources include petroleum, small deposits of chromium ore, copper, iron ore, mica, silver, tungsten and zinc and gold(50). The total cultivatable land area of the country is estimated to be about 200 million *feddan*[1], only about 41 million *feddan* are under crop production (51). Sudan has the largest irrigated area in Sub-Saharan Africa and the second largest in the whole of Africa, after Egypt. Rain-fed agriculture covers the largest area in Sudan (52).

3.2 Demography

Sudan's total population is 39.154,490 (53), 29.8% urban, 63.2% rural and 7% nomads. The structure of population by age denotes first a very young demographic profile, with 62.2% of population aged less than 25 years and a child dependency ratio of 81.6%. The age structure is then as follows: less than 15 years of age are 42.6% (male 8,718,975/female 7,964,829); 15-64 years: 54% (male 10,606,790/female 10,508,986); 65+: 1.3% (male290, 779 /female 222,142). Sex ratio for the total population is 105.21 and at birth is 109.19. Infant and under five mortality rate for the total population is 86 deaths/1000 and 122 deaths/1000 live births respectively. Life expectancy at birth and at age 20 for the total population is 57 and 48 years respectively (53). Percentage of literate population (15-24) according to MDGS(9..3), is to reach level (100%) literacy to (15-24) in 2015, currently in 2008 the level for both sexes is 61% and 66%,56.1% for males and females respectively(53). The rate of growth is 2.66, crude birth rate is 26.30, total fertility rate is 6.00 and crude death rate is 13.40(53).

About 5% of nationwide, urban and rural households had a size of one person compared with 2% among nomadic households. Household of five was reported to be 12%, 14% and 16% of urban, rural and nomadic households, respectively. Opposite to expectations, the percentage of households with a size of 10 people or more was highest in urban household and this may be due to rural-urban migration.

[1] One feddan = 0.42 Hectare

3.3 Economy

With its total area of 1690 million hectares, Sudan has relatively large economic resource potential in terms of its endowment of natural resources, including arable and grazing land, water and mineral resources and different climatic zones. Despite this, the majority of the population lives in absolute poverty and the economic and social development has been below the expectations (54). The GDP per capita on purchasing power parity (PPP)(US $) 1,900 in 2004,2100 in 2005, 2,400 in 2006, 1,900 in 2007 and 2,200 in 2008(55) and the monthly per capita consumption in Northern Sudan was 148 SDG in 2009 and 46.5 % of the population fall below the poverty line, with 26.5% of the urban and 57.6 of the rural population falling below the poverty line(53). Agriculture is considered to be the backbone of the Sudanese economy. Recently, oil accounts for over 80% of exports and 40% of public revenues (56).

Investigation of feasibility for achieving the Millennium Development Goals (MDGS) of reducing poverty by half by the year 2015 for Sudan showed that the major results are to achieve the MDG on poverty; Sudan's GDP needs to grow by an annual rate of 7.2%, which requires an investment rate ranging from 35% to 42% of GDP. Given Sudan's past growth performance, and assuming that Sudan will be able to maintain a GDP per capita growth rate of 2.2 (equivalent to a GDP growth rate of 5), an optimistic reasonable horizon to reduce poverty by half will need 28 years starting from 2001, almost double the horizon implied by the MDGS(57).

Sudan belong to the Medium Human Development countries in the categorization established by the UNDP with a Human Development Index equal to 0.53 in 2007(58) and 0.52 in 2008(59), putting the country in the 150 rank in the rank of 180 countries.

3.4 Political context

Sudan's political and administrative structure has been based on a presidential republic and federal system since 1991.The level of government is subdivided into federal, state and local governments. State is administered by *Wali* (governor) with a cabinet of 5-7 ministries and the localities are administered by a commissioner. The federal level of the government is concerned with policy making, planning, supervision and coordination. The state level of the governments is responsible for planning, policy making and implementation at state level, while the localities are responsible for policy implementation and service delivery (60).

Sudan has suffered from civil wars for the most of the period since independence in 1956. The effects of these civil conflicts have significant effects on health, nutrition and population. More than 2 million people died and more than 4 million are internally displaced or became refugees. A comprehensive peace agreement was signed in 2005 ending the long civil war in the south and then led to the secession of South Sudan on July9, 2011. However, in 2003, another civil war started in Darfur and resulted in many deaths and the displacement of hundreds of thousands of civilians in Sudan, particularly to neighboring Chad (60).

3.5 The heath system

The health system in Sudan is structured into three layers. These are the Federal Ministry of Health (FMOH), the State Ministry of Health (SMOH) and the Local Health System. The FMOH with its 10 general directorates is the main layer for policy making, strategic planning, coordination, international relations and resource for technical guidance and support for the states.

Health services are provided through different partners in addition to Federal and State Ministries of Health, Armed Forces, Police, universities, private sector both profit and philanthropic and the civil society. However those partners are still working in isolation due to lack of coordination system (54).

The FMOH is linked to 25 state Ministries of Health (15 of which are in the Northern Sudan). The second layer is composed of 25 State Ministries of Health that share with FMOH the responsibility of planning, legislation and financing. The third layer in the federal setup is the locality level. The local health system is based on the district health system approach and emphasizes the primary health care principles represented in decentralization, community participation, intersectoral collaboration and integration of services. Local councils are responsible also for water and sanitation services. The district health administration is led by the district health administration team, which supports the process of bottom-up planning (61).

Primary health care is delivered through basic health units (dispensaries), which are structured and staffed to deliver integrated primary health care. The health centers are the referral point for the lower level facilities and are headed by a physician. Health centers are managed by localities. The rural hospitals are managed by SMOH and have a capacity of 40 to 100 beds. Tertiary level includes teaching and specialized and general hospitals, and it is located in the state capitals and managed by SMOH. FMOH operates 21 tertiary level hospitals and specialized centers (61). Rural/community hospitals cover 100,000-250,000 per population; health centers cover 20,000-50,000 and Basic health units (dispensaries) cover 5, 000(61).

The total health workforce is estimated to be around 62,483 health personnel classified into more than 20 categories. There are 8,379 Physicians, 697 pharmacists, 17,923 medical assistants, 16,826 nurses and 12,159 midwives. The population ratio per 10,000 for nurses, for physicians is 2.4 populations. The attrition rate of physicians and pharmacists to the private sector and abroad is very high. From the 17,000 registered physicians in the Sudan Medical Council registry since 1936 only 8,379 are working in the public health sector. The gap in human resources is huge; the table (2) below shows this gap (60).

Table 2: Gap in human resources for health

Category	Current	Needed	Gaps
Specialized Doctors	1000	5000	4000
Nurses	16,000	80,000	64,000
Midwives	16,629	26,000	9,371
MAs	6,000	26,000	20,000

Source: annual statistical report 2005

The government spending on health has remained at less than 1% of Gross Domestic Product (GDP), ranking Sudan among the lowest in the world.

The epidemiologic profile of Sudan looks like that common to Sub-Saharan African countries; malnutrition and communicable diseases dominate the health scene with high vulnerability to outbreaks. The main cause of morbidity and mortality are infectious diseases like malaria, TB, *Schistosomaisis*, diarrheal diseases, acute respiratory tract infections (ARIs) and protein energy malnutrition (61).

CHAPTER 4.METHODOLOGY

4.1 Overview

For this cross sectional retrospective study, data of reported PTB cases collected from TBMUS satisfied the inclusion and exclusion criteria for data collection. Eligibility for TBMU to be included in this study was a functioning TBMU with TB registers for a two year period (2007 and 2008) and to exclude TBMUs in federal and state hospitals that do not have TB registers. Out of 46 TBMUs only 33 satisfied the criteria for inclusion in this study. Out of the 33 TBMUS that were included in the study, 11 were general state hospitals, 2 were federal referral hospitals, 19 were government health centers, and one was a NGO health center. The socio-demographic variables collected from the reported TB cases were the age, sex, and residency address of the TB patient and the treatment unit.

4.2 Research Design and Approach

Quantitative research with descriptive cross-sectional and retrospective study design was used for this research. This is an attempt to observe and illustrate the geographical distribution of PTB in Khartoum State by using GIS. Secondary data on PTB cases was obtained from the TB Registers (TBR) and TB Treatment Cards (TBTC) of 33 TB management units (TBMUs) out of the 46 functioned ones during January2007-December 2008. TBRs and TBTCs contain information on the patient's age, sex, residence, patient's category: new or re-treatment (relapse, treatment after default, failure and whether transferred from another TBMU) and treatment outcome (cure, complete, defaulted, failure, died or transfer out to other TBMUs within or out the state).

4.3 Data Source

Shape files of population geo-coded to AUs of Khartoum states obtained from Central Bureau of Statistics (CBS) and population density were calculated for all AUs using (Microsoft Office Excel 2007) based on the population per square kilometer. TRs and TBTCs from study sites were accessed to record the details of PTB patients as discussed in the following sections. Data collected were date of patient registration, TBMU, sex, age, Address, treatment facility or Direct Observed Therapy center (DOT), date of treatment, category of patient, results of sputum smear microscopy and treatment outcome variables. Shape files of geographic coordinates for 26

TBMUs were obtained from SMOH. TB Case Notification Rate (TBCNR) was calculated based on the number of total PTB cases (new &re-treatment) and total population of each AU using (Microsoft Office Excel2007). Due to unavailability of socioeconomic data at the AU level in the results of the 4th (1993) and 5th census (2008).The images from areas with high and low PTB intensity obtained from Google Earth (with eye altitude of 3013 feet) and was used as proxy indicator to show socioeconomic level of these areas.

4.4 Software and devices use

Global Positioning System (GPS, **Garmin 60CSx...)** obtained from GIS expert working with the UNDP (Mr.Amr Kamabal) and used for collection of exact geographic coordinates for 20 TBMUs by the researcher. Geographic coordinates of BLOCKs and AUs were in the Base Map of Khartoum State, which was obtained from SMOH. The Khartoum base map was linked to ArcView 9.3 (ESRI,Redlands,CA), obtained from the University of Twente, faculty of geo-information science and Earth Observation, Netherlands as part of training materials of the GIS training course attended by the researcher in July 2010. ArcView 9.3 consists of three basic parts (ArcCatalog, ArcMap and ArcToolbox). Information about PTB cases reported in 2007 and 2008, population density, TB case notification rate, case finding indicators, socio-economic indicators and Google maps of slums and squatter areas in Khartoum state were linked to ArcMap of the ArcView 9.3 to create visual maps of AUs and TBMUs to study relationships between these layers, to locate potential transmission areas of PTB in the community of AUs and to display case finding indicators of PTB cases. Exact GPS location of each patient was not collected because of the workload (5,203 PTB cases), cost and ethical consideration. Instead patients were allocated to TBMUS, AUs and BLOCKs (*Hara*). Statistical analysis using SPSS statistical package (PASW® Statistics 18) and (Microsoft Office Excel2007) was used to calculate case finding and treatment outcome indicators. In addition, combinations of descriptive and analytical approaches were used to meet the objectives of this research.

6.2 Study Area

In Khartoum, where the study was conducted**,** TB services are provided through 54 Tuberculosis Management Units (TBMUs) as diagnostic and treatment sites and Directly Observe Treatment centers (DOTS) as treatment centers. A certified nurse (medical assistant) is the designated person responsible for the management of TB patients assisted by a microscopic unit run by a laboratory technician or laboratory assistant and clerk/ statistician responsible for the reporting(7). A modified eight months regimen was implemented since January 2006(62).

The TB Programme in Khartoum state is a well-functioning Programme compared to other states. It has good political commitment in the state, 100% coverage of TBMUs and DOTs centers and a good reporting system. TB services in Khartoum state are delivered through three categories of health facilities:

1. Federal level, consisting of federal hospitals, which are specialized chest hospitals or specialized chest units in big hospitals (9 centers in total).
2. State hospitals, health centers and PHC units that belong to Khartoum state Ministry of health.
3. Internally Displaced Peoples (IDPs) health units. These are centers run by the Sudan Council of Churches (NGO) and offers health services to the IDPs.

Tables (3, 4, 5 and 6) show the case finding and treatment outcome indicators of NTP for year 2007 and 2008(6).

Table 3: TB case finding, 2007

Khartoum	New +ve	Relapse	Negative	Extra-pulmonary	Total
2007(Actual)	3299	567	2437	1267	7570
%	43.6	7.5	32.2	16.7	100.0
Estimated	4817				
Case Detection Rate	68.5				

Table 4: TB Treatment Outcome 2007

Total registered	**cured**	**completed**	**died**	**Failure**	**Defaulted**	**transferred out**	**Total**
3299	**2018**	**650**	**71**	**23**	**245**	**77**	**3084**
%	**61.2**	**19.7**	**2.2**	**0.7**	**7.4**	**2.3**	**93.5**
success	**80.9**						

Table 5: TB Case finding 2008

Khartoum	New +ve	Relapse	Negative	Extra-pulmonary	Total
2008(Actual)	2631	680	2267	1007	6585
%	40.0	10.3	34.4	15.3	100.0
Estimated	4747				
Case Detection Rate	55.4				

Table 6: TB Treatment outcome 2008

Total registered	**cured**	**completed**	**died**	**Failure**	**defaulted**	**transferred out**	**Total**
2631	**1419**	**578**	**53**	**20**	**312**	**247**	**2629**
%	**53.9**	**22.0**	**2.0**	**0.8**	**11.9**	**9.4**	**99.9**
Success rate	**75.9**						

The state was chosen for this study because:

- Availability of a reason basic map for GIS use
- High feasibility of the study area compared to other states
- Among all communicable diseases TB control given the highest priority by the state government.
- The state with highest case detection rate (CDR) among other states (55.4%)
- Is the state with the highest number of Internal Displaced Peoples (IDP) from different part of the country, living in slum and squatter areas located in the three towns of city.
- The state represent all ethnic groups of the country
- Urban population constitute 81% (most of them living inthe tripartie city of khartoum)and rural only 19%. Rural-urban migration was clearly evident from 1993 and 2008 census and available data indicates that there is significant disparities between urban areas and poverty increased with migration from rural to urban areas.

4.4 Study Population

All PTB cases enrolled in the TB registers and TB treatment cards of the TBMUs in Khartoum state over a period of two years (Jan.2007-Dec. 2008) meeting the inclusion criteria set by the researcher are eligible as study population.

Inclusion criteria:

- All PTB cases new and re-treatment enrolled in the TB registers and treatment cards of all functioning TBMUs in Khartoum state for the year 2007 and 2008 were included.

Exclusion criteria:

- Pulmonary TB cases without ***informative address***[2] were excluded.
- All PTB patients enrolled in hospitals (federal and/or state) that had no TB registers for the year 2007 and 2008 were excluded.

4.5 Study Variable and definitions (63-65)

Date of patient registration: is the date when the patient diagnosed and registered as a TB patient in the TBMU.

TBMU: Is the basic management unit of NTP that serves maximum of 100,000 populations and is a centre for diagnosis, treatment recording and reporting.

Sex: Physical sex of the patient.

Age: Age in years of patient at last birth day.

Address: Is location where patient live (residence), house number, street and block number or locality and AU.

Treatment facility or DOTS: A DOTS centre is the most peripheral site at which treatment is given, bringing the services close to the residence of the patients as possible. A DOTS centre can be any health facility.

Date of treatment: is the date when the TB patients enrolled in one of the category of treatment and start anti-TB chemotherapy.

Category of patients (four categories):

[2] *Address showing the exact name of the AU and/or block/hara number*

1. New . Is a TB case in HW has diagnosed TB for the first time and has decided to treat the patient with a full course of TB treatment.
2. Re-treatment:
    a. Relapse. A patient previously treated for TB who has been declared cured or treament completed, and is diagnosed with bacteriologically positive (smear) TB.
    b. Treatment after failure. A patient who is started on a re-treatment regimen after having failed previous treatment.
    c. Treatment after default. A patient who returns to treatment, positive bacteriologically, following interruption of treatment for two months or more
    d. Transfer in . if the patient was transferred to another unit for treatment continuation.
    e. Others. All cases that do not fit the above definitoin. This group include **chronic** case (a patient who is sputum positive at the end of re-treatment regimen.

Results of sputum smear microscopy. The outcome result of sputum microscopy after staining it with Zeihl-Neelsen stain to identify acid fast bacilli in the sputum of the patient and it can be either positive or negative result.

Treatment outcome (64)**:**

a. **Cured**. A patient whose sputum smear or culture was positive at the beginning of treatment but who was smear- or culture- negative in the last month of treatment and on at least one previous occasion.
b. **Completed**. A patient who completed trreatment but who does not have a negative sputum smear or culture result in the last moth of treatment and on at least one previous occasion.
c. **Treatment success** is the sum of cure and completed.
d. **Failure**. A patient whose sputum smear or culture is positive at 5 months or later during treatment. Also included in this definition are patients found to harbour a MDR strain at any point during the treatment, whether they are smear-negative or positive.
e. **Default**. A patient whose treatment was interrupted for 2 consecutive moths or more.
f. **Died**. A patient who dies for any reason during the course of treatment.

g. **Transfer out**.A patient who has been transferred to another recording and reporting unit and whose treatment outcome is unknown.

TB case notification rate: is the number of TB cases reported to the NTP per year per 100,000 populations and calculated for new cases or new and relapses or for all TB cases (65).

TB Prevalence rate: is the number of cases TB (all forms) in a population at a given point in time (sometimes referred to as "point prevalence") (64).

4.5 Data Processing, Analysis and Interpretations

Data of all PTB patients detected and registered in one of the TBMU's in 2007 and 2008 were collected by the researcher and two research assistants from the EpiLab after getting permissions' letter from the state TB coordinator. The data was entered in the database of SPSS statistical package (PASW® Statistics 18) by two data entry clerks (one from EpiLab and one hired for this purpose) independently. Afterwards the researcher applied the ex/inclusion criteria during data cross-checking, validation and cleaning. After the completion of data cross-checking, validation and cleaning all collected TB registers and TB cards were returned back to their TBMUs. Data were collected from 33 (with complete data for the two years) out of 46 functioned TBMUs during 2007 and 2008.

The infrastructure of the NTP and Epidemiological laboratory (EpiLab) was used for data collection, entry, processing and analysis.

A total of 7,167TB cases (Pulmonary and EPTB) were entered in SPSS (PASW® Statistics 18). After the completion of cross-checking the data for consistency, cleaning, validation and applying the ex/inclusion criteria, 985 patients records were excluded because they were EPTB cases, 662 cases were excluded because of non-informative addresses, 317 were reported addresses out the state were excluded from the mapping at AUs level but were however included in the mapping by TBMUs, and the researcher finally remained with 6,182(3156 and 3026) PTB cases for 2007 and 2008 respectively. An aggregate of 2694 out 3156 PTB cases (85%) reported in 2007 and aggregate of 2509 out of 3026 cases (83%) reported in 2008 were used for mapping cases by AUs. An aggregate of 3156 reported in 2007 and aggregate of 3026 PTB cases reported in 2008 were used for displaying TB case finding and treatment outcome indicators by TBMUs.

Because there was no available data on socio-economic characteristics at AUs and blocks level, numerous studies conducted in different areas of Khartoum state and Google maps of areas with high TB case notification were used as proxy indicators for socio-economic characteristics. Data were entered in SPSS statistical package (PASW® Statistics 18), transferred to excel and then joined with ArcGIS (Arc GIS version 9.3, ESRI). This version consists of ArcMap for creating maps, entering and editing spatial and non-spatial data, the variables of PTB joint to Khartoum base maps through GIS (shape file format). These maps have shape files for the state, localities, administrative units and blocks.

Figure 6: shows different layers we used in the ArcMap of ArcView 9.3

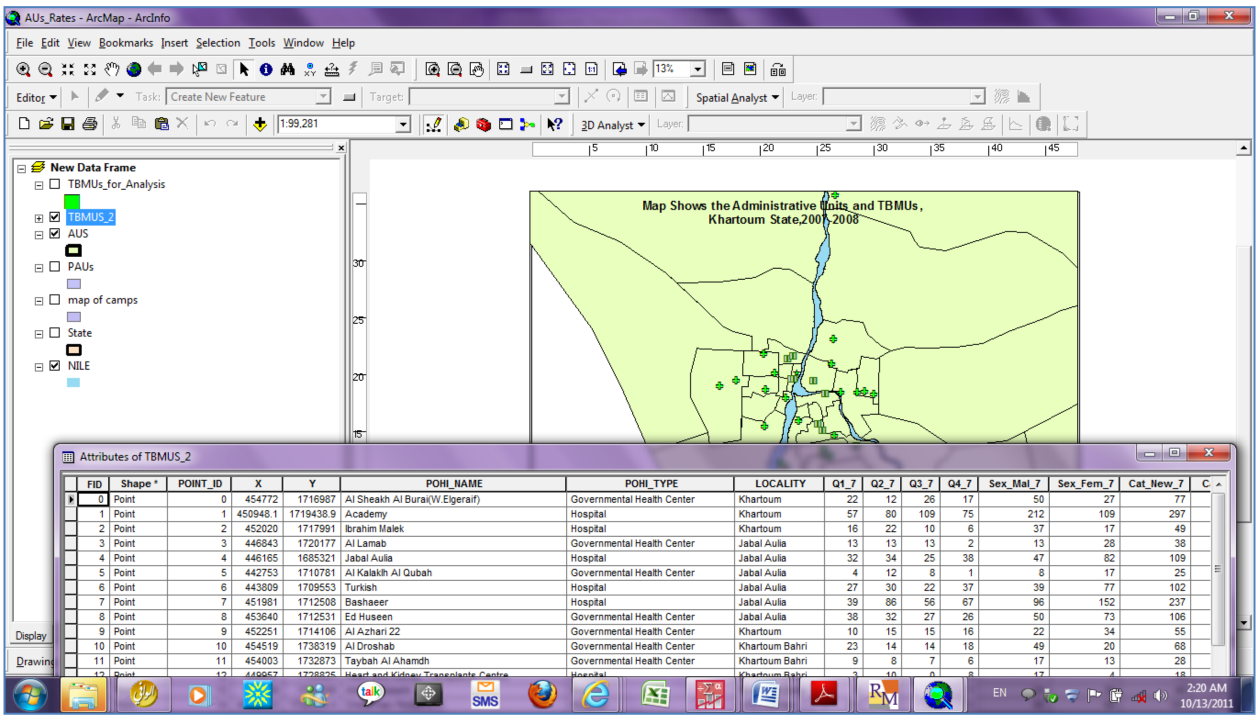
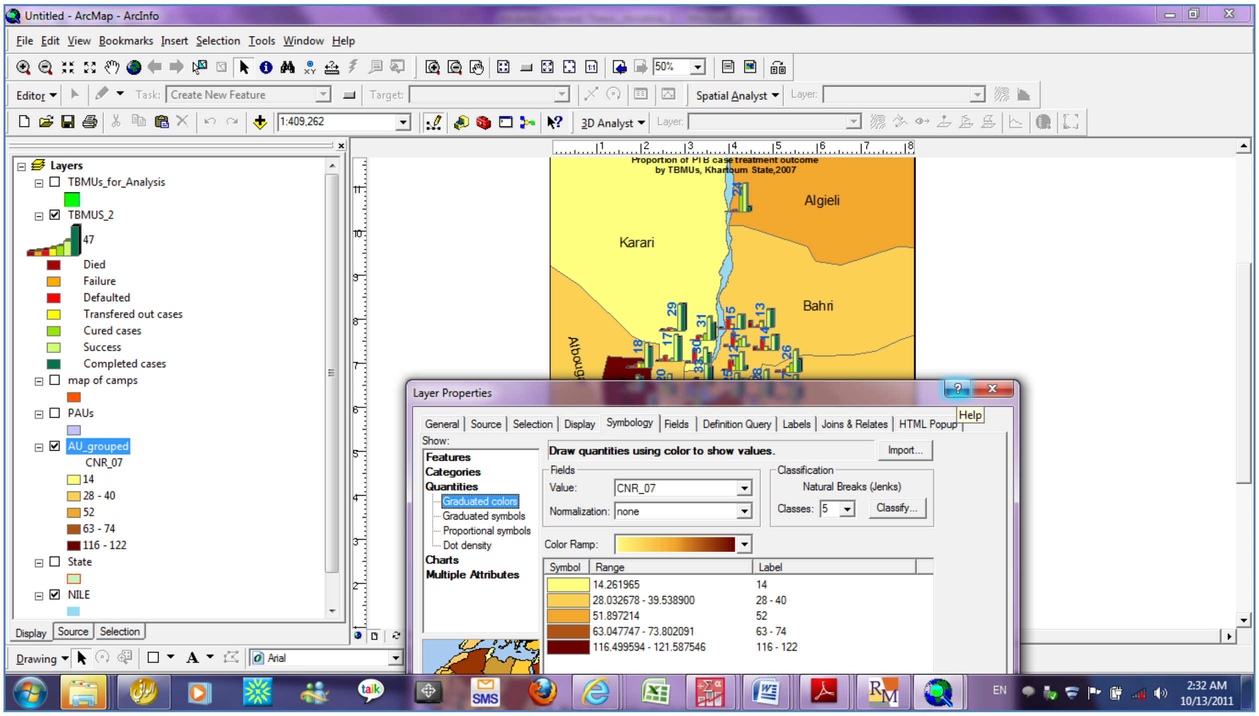


Figure 6 shows different layers which were used for purpose of mapping and illusttating the geographic distribution of PTB in Khartoums State were the TBMUs, AUs, Poulation administrative units (PAUs) localities,IDPs camps and the Nile. Also this figure shows sample of excel table with PTB varibles joint to the attributes of the base map of Khartoum.

Figure 7: shows layers properties



This layer properties with the symbology tab that we used for the PTB mapping and generating different charts.

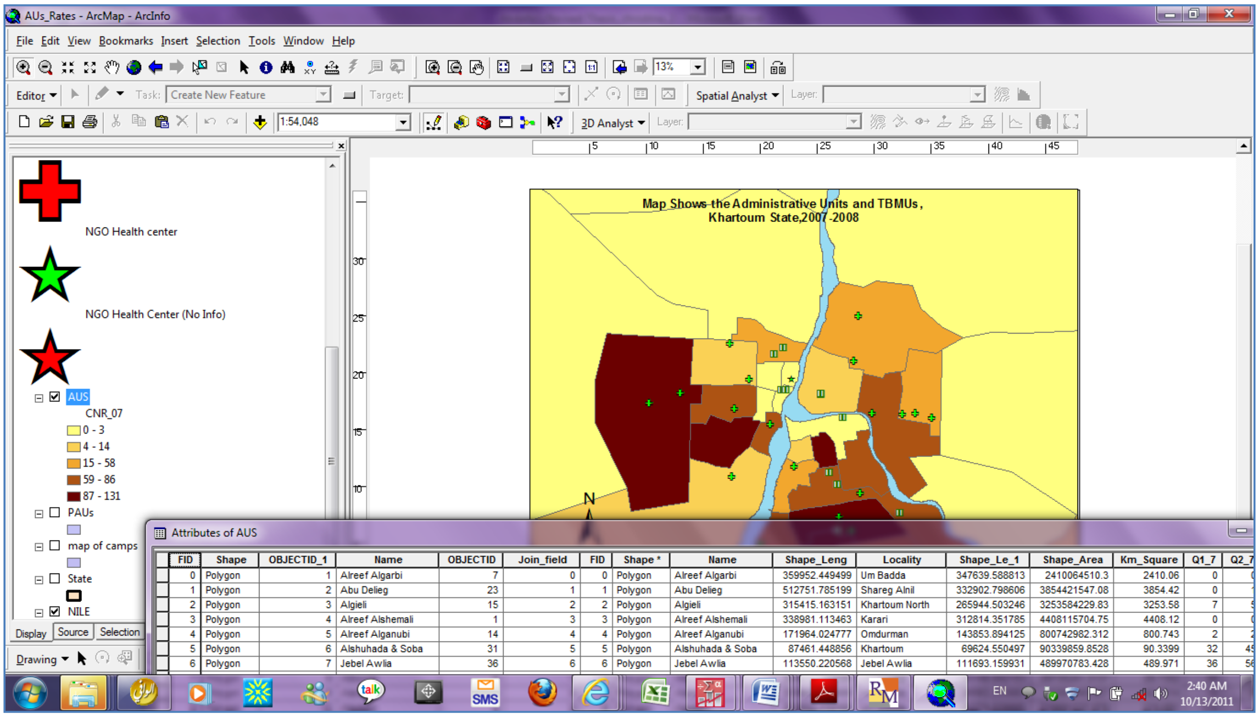
Computer hardware, A Pentium based PC running Microsoft Windows 7 was used to complete the study and the related GIS application.

CD-RM, CD-RW, jet USB Flash and mobile hard drives used to archive all the data related to this research. A plotter printer: HP 750C, A0-size Color Inject Plotter was used to produce high quality hardcopy papers. A laser printer was used to produce A4 size hard copy paper maps.

Spatial analysis:

A thematic map of TB case location was overlaid on a base map of Khartoum state to identify the number of TB cases per administrative unit and their relationships to socio-demographic, socioeconomic and environmental factors (figure 8).

Figure 8: shows the attribute table and layers and the thematic map (choropleth map) of the Administrative Units.



Spatial scan statistics with *SaTScan software at (http://satscan.org*) planned to be used to investigate clustering patterns for PTB and to suggest reasons for the observed spatial distributions; and to test whether TB cases are distributed randomly over space, and if not, to identify significant spatial clusters (24). However, we were unable to collect geographic coordinates for the 5,203 PTB patients reported in 2007 and 2008 because of the workload, cost and ethical consideration and therefore spatial point pattern not studied. Cases with informative addresses at the block level (have block name and number) for the two years period were 2,462 out of the 6,182 PTB cases constituting 40% scattered over the 36 AUs, therefore mapping at the block level was not done.

6.1 Methodological Limitations

In Sudan as in most of the developing world the data set that are considered basic for GIS are available. However, this data is usually incomplete and contains errors and uncertainty, which makes it of poor quality. Complete information about PTB in the TBR and TBTC is rare in most developing countries and Sudan is not an exception. However, TB data compared to other disease is far better (36). Given the retrospective nature of this study, we were limited to residential addresses that were found in the TBRs and TBTCs. These addresses do not document the exact locations of the patients and only 1447/3156 (46%), 1015/3026 (34%) of TB patients in 2007and 2008 respectively have addresses with block number. 298 (9%), 364 (12%) cases with non-informative addresses in 2007 and 2008 respectively and 164 (5%) in 2007,153 (5%) in 2008 with addresses out Khartoum state. This lack of exact locations of the patients is a weakness, which could be considered and corrected in a prospective study.

Data was not obtained from 13 TBMUs either because no TBRs, no TBTCs or the available data found was for only one year there for these 13 TBMUs were excluded from the study, remained only with 33 TBMUs (72%), which satisfied the inclusion criteria. Exact geographic coordinates for the reported PTB cases were not collected because of the workload (5203 cases), time and cost. Not all reported patients had informative address at block level, only 41%, which limited the possibility of mapping at block level.

The other limitation is that GIS is expensive software and not easy to use, however the price of GIS software has fallen in the last year but still is expensive and people with GIS training are very busy and expensive(22).

4.7 Ethical Considerations

This study is an implementation research that includes research questions, which embedded in (are we doing the right things?) instead of (are we doing things right?) and this why this research has to comply with the requirement of medical research boards. Despite the fact that study deals with records of TB patients retrospectively and does not directly involve any patients or names of patients and is aimed at improving the TB Programme quality indicators, approval of the study was obtained from the Sudan National Research Ethics Review Committee (Appendix).

CHAPTER 5.STUDY FINDINGS AND ANALYSIS

Results

a. Study area: figure 9 shows 36 AUs and 46 TBMUs targeted for study. TBMUs are represented in different shapes and colours, cross ✚ shape represent government health centers, star ★ shape represent NGOs health center and the letter capital **H** represent hospitals, green color shows TBMUS where data was found and collected and red color shows where data was not found during the visit for data collection and therefore not collected. Part of TBMUs overlapped each other because they are located within short distance from each other and therefore not clearly shown in this map.

Figure 9: shows the study area AUs and TBMUs

b. Study population

Out of 46 functional TBMUs during the year 2007 and 2008 and planned to be included in this study, information was attributable for 33 TBMUs (72%). A total of 7,167 TB cases (PTB & (EPTB)) was the result of the data entered in SPSS (PASW® Statistics 18). 985 (14%) were excluded from the total TB cases because they were EPTB. However, out of the 6,182 PTB cases, only 5,203 (84%) were found with informative addresses (84%).

The characteristics of the study population used were the age, sex and residence address.

Age**:** The ages of the study subjects ranged from 6 months to 100years. The mean age was 31.82 years, those who were ≤15years old represented 14.3% of the total study population while those between 15-24 ,25-44,45-64 and 65 years old and more were 21.2%,41.2%,17.1% and 6.2% respectively. Of the total sample age group 25-44years counted 41%.

Figure 10: shows the age distribution of the mapped study population for the two years

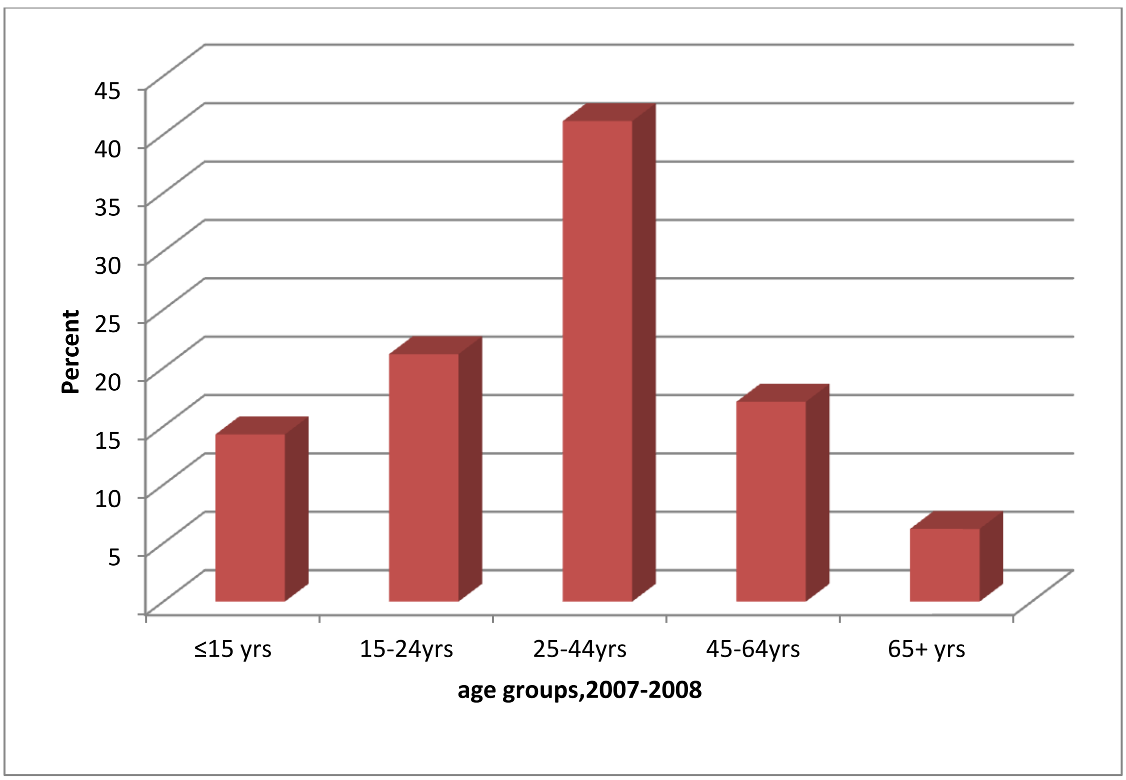


Figure 11: Shows the age distribution of the mapped study population for the year 2007

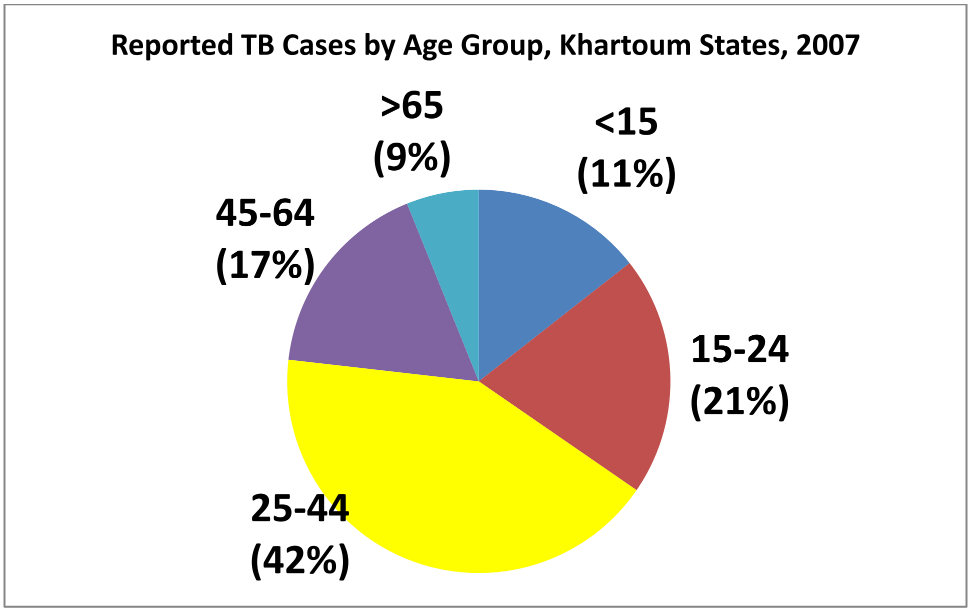
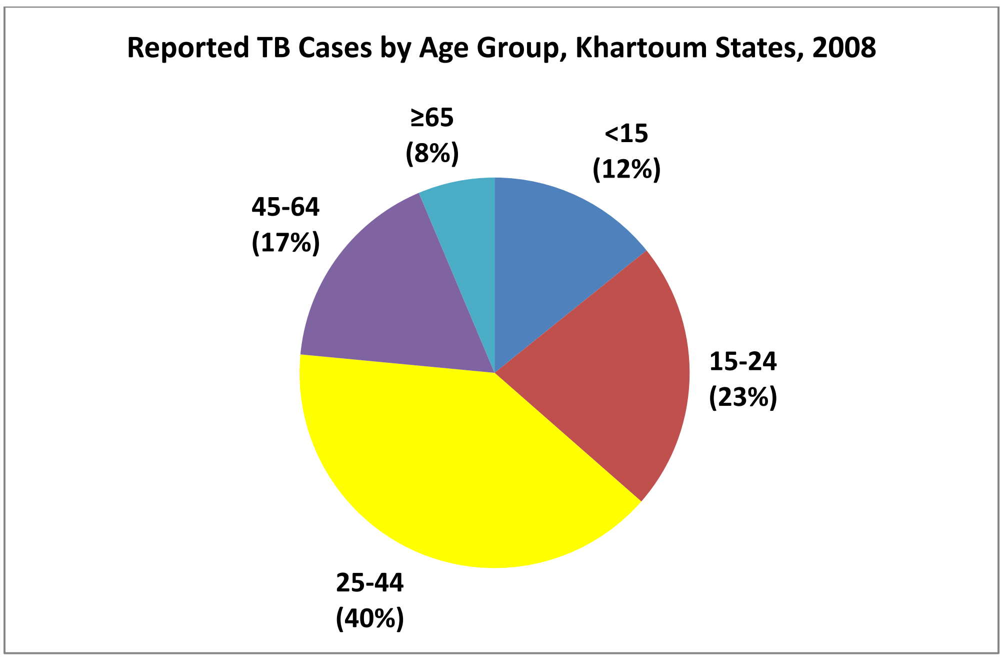


Figure 12: shows the age distribution of the mapped study population for year 2008



Sex**:** With a total number of 6182 cases, females represented (n=3173) 51.3% of the total study subjects while males were (n=3009) 48.7%. For all age groups the numbers of female were higher than male except in the extreme age groups 15 and less and 65+, males are higher than female, but none of the differences make statistical significance.

Figure 13: shows the sex and age distribution of the mapped study subjects according to year 2007-2008

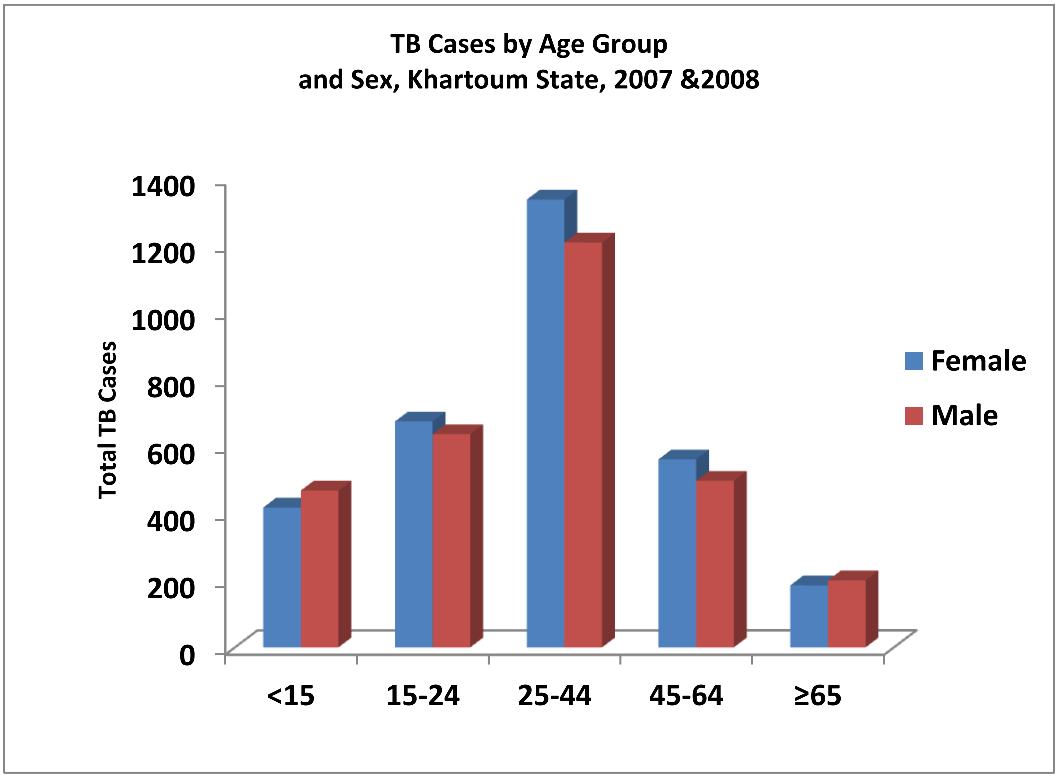


Figure 14: shows the sex and age distribution of the mapped study subjects according to 2007

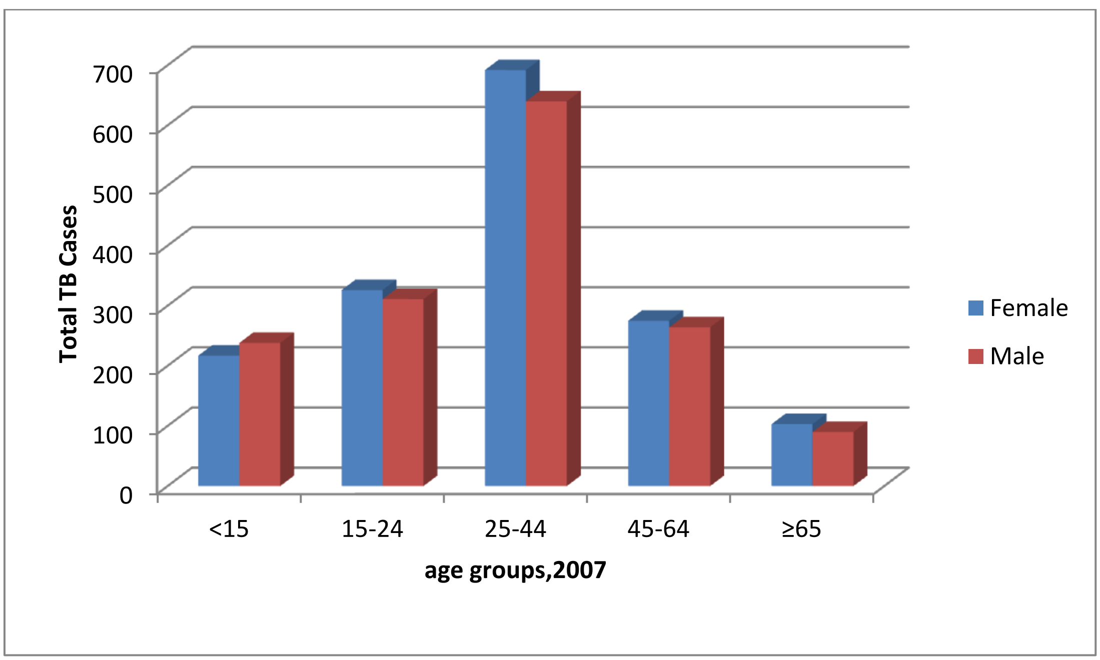
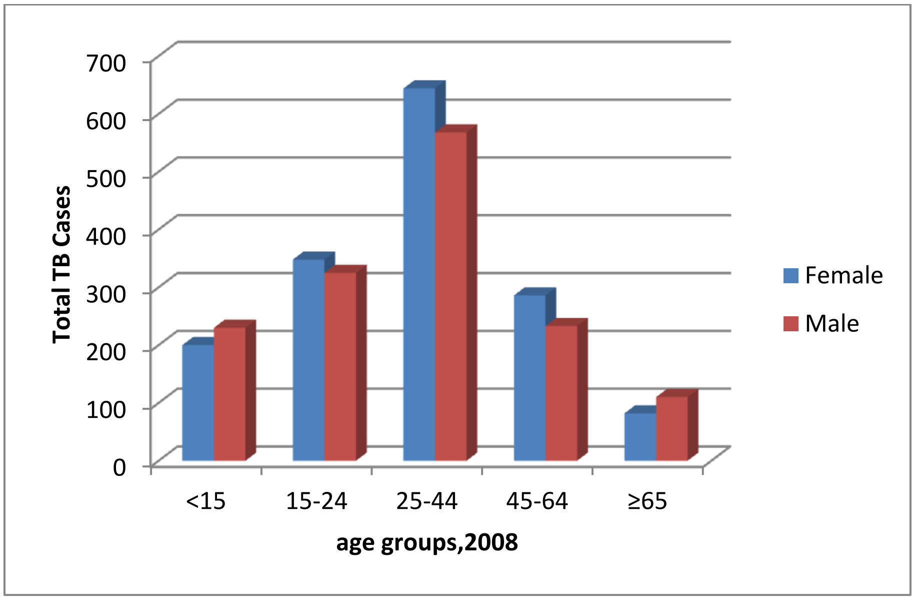


Figure 15: shows the sex and age distribution of the mapped study subjects according to year 2008



Residence**:** Five percent (317) of the total sample were residing outside the study area the years 2007-2008 therefore we excluded these cases. Similarly 662 (11%) reported either non-informative or no address of residence was found in the TBR or TBTC; and hence then too were excluded. Information about housing conditions of the mapped subjects (number of rooms per house, number of persons per house and number of persons per room) was not recorded in the TBR or TBTC. Therefore these details are lacking in analysis.

Marital Status, Education, Occupation and Income**:** No information about the marital status, education, occupation and income was available in the TBR or TBTC and we did not attempt to collect these details for the study subjects due to time limit and cost considerations. Instead, studies on poverty and snapshot photos from the residential areas were made by Google Earth maps and used as proxy indicators of socioeconomic status in areas with high incidence of TB.

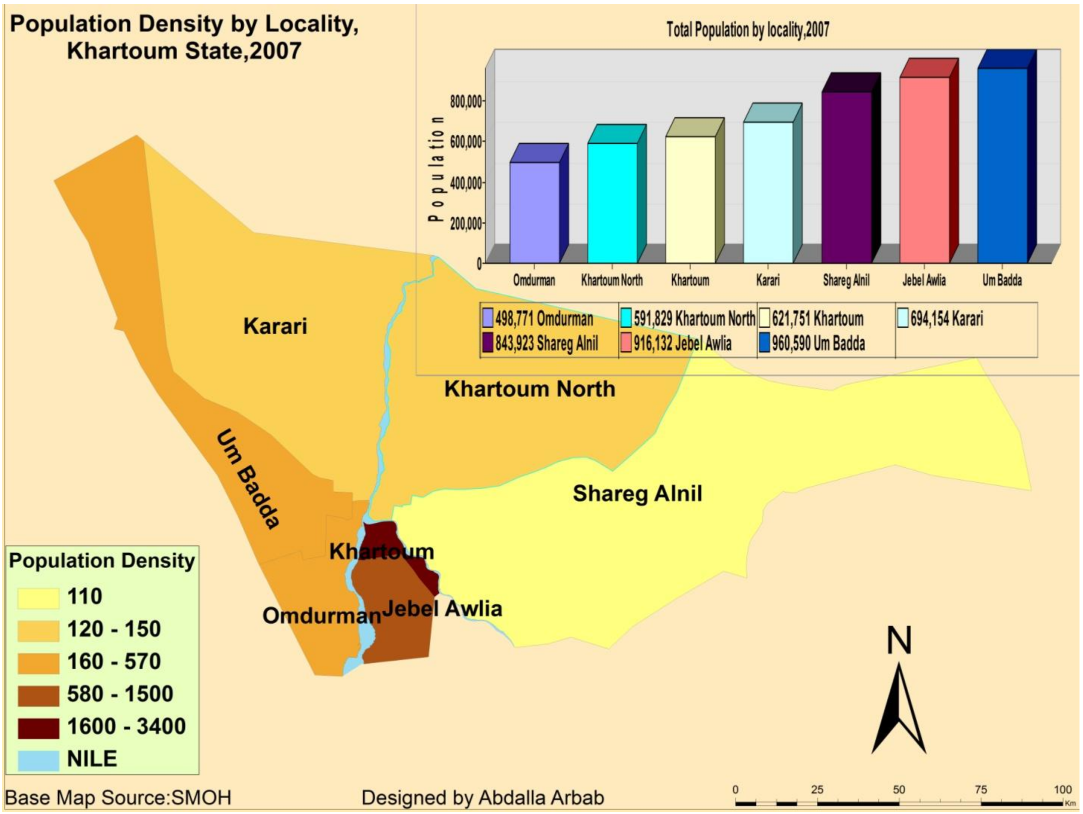
c. Population data for the study sites

The following figures 16-20 show the results produced by mapping population density using ArcGIS by locality and by AUs according to 2007-2008.

Population Density of Khartoum state:

Khartoum state is the most densely populated state with considerable number of IDPs and city slums. Overall Population density was 235 and 242 persons per square kilometer for 2007 and 2008 respectively.

Figure 16: shows population site and density of seven localities Khartoum state according to year 2007.



Reading map in figure 16 together with the map in figure 17 we will understand that the locality with large size have less population density compared to the one with small size and have high population density and figure 17 shows the actual distribution of population by the areas where they live. Even in Jebel Awlia locality population concentrated alongside river Nile and the rest of locality is either empty or agriculture areas. Similarly this applied to other localities. Population concentrated in Khartoum locality which the smallest by size. The same pattern applied to the year 2008 in figure 18.

Figure 17: shows population density with overlaid PAUs

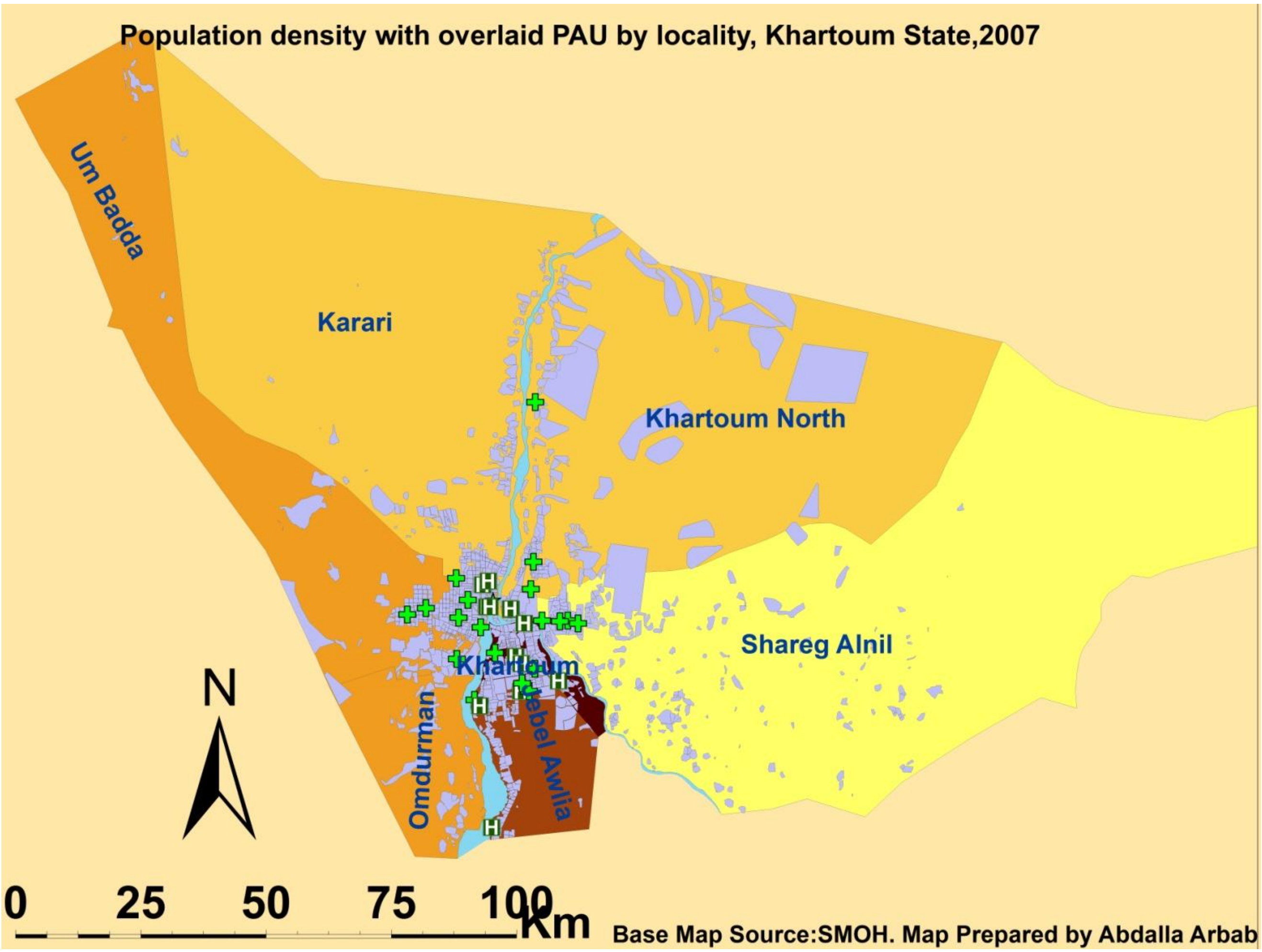


Figure 18: shows population density of Khartoum state seven localities for year 2008

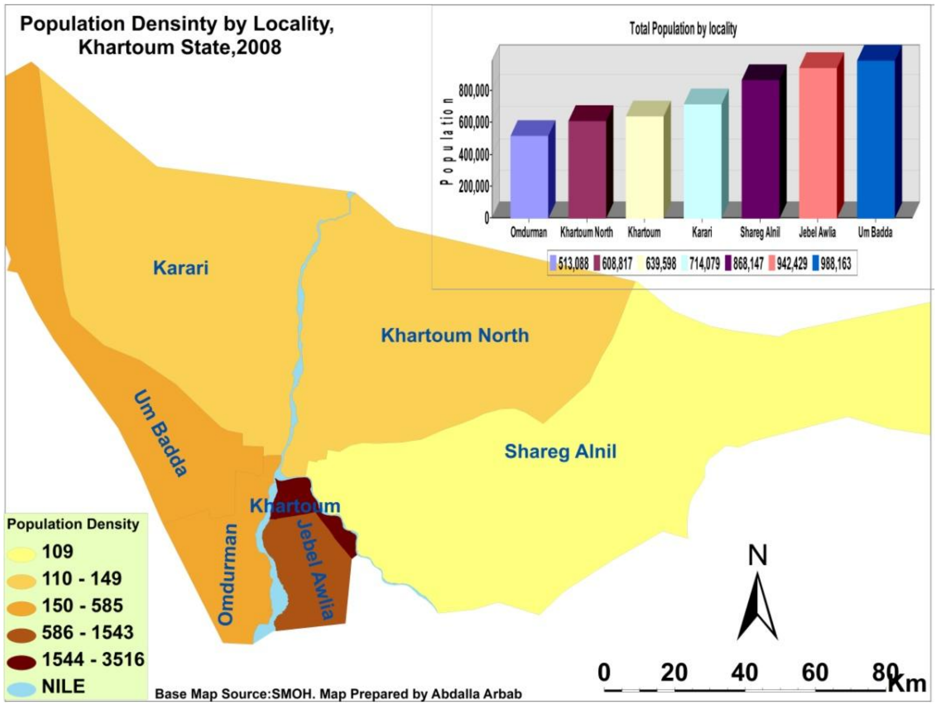


Figure 19: shows population density by Administrative Units according to year 2007

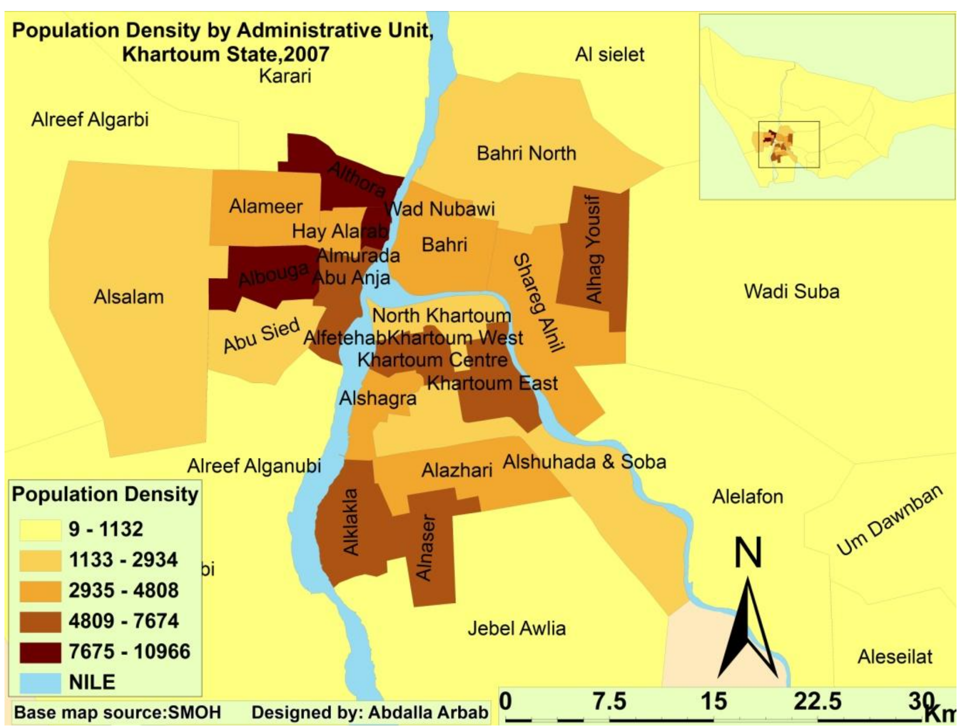
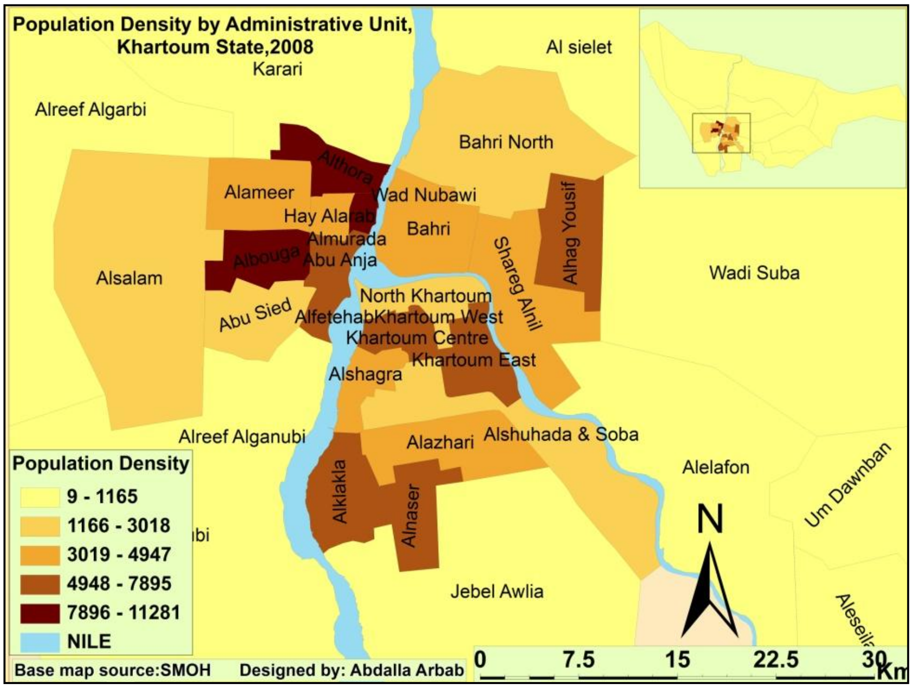


Figure 20: shows population density by Administrative Units according to year 2008.



The following figures show maps related to PTB epidemiology for the study area.

Figure 21: Shows PTB notification rate TBMUs by AU for year 2007

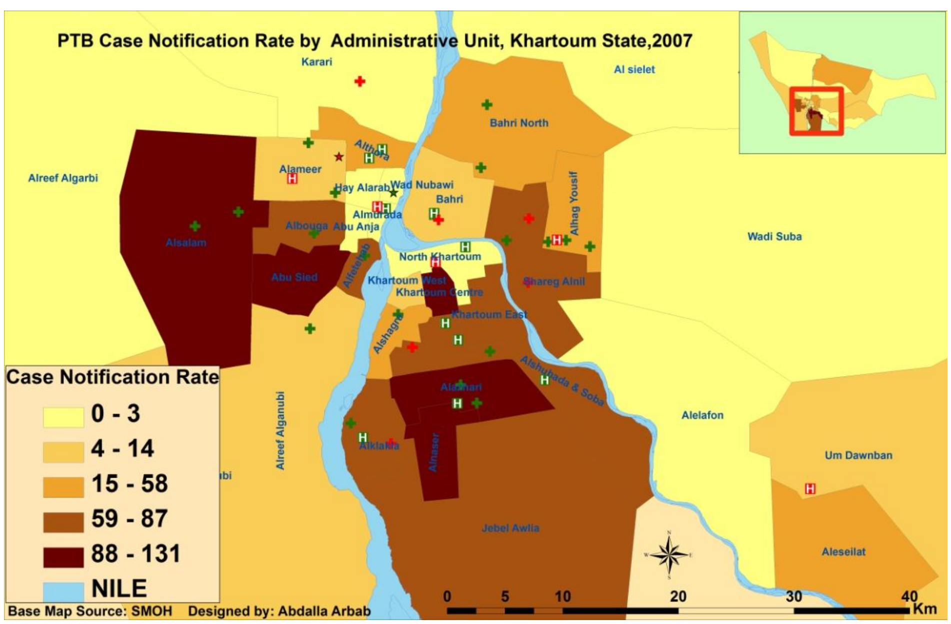


Figure 22: Shows PTB case notification rate and TBMUs by AU for year 2008

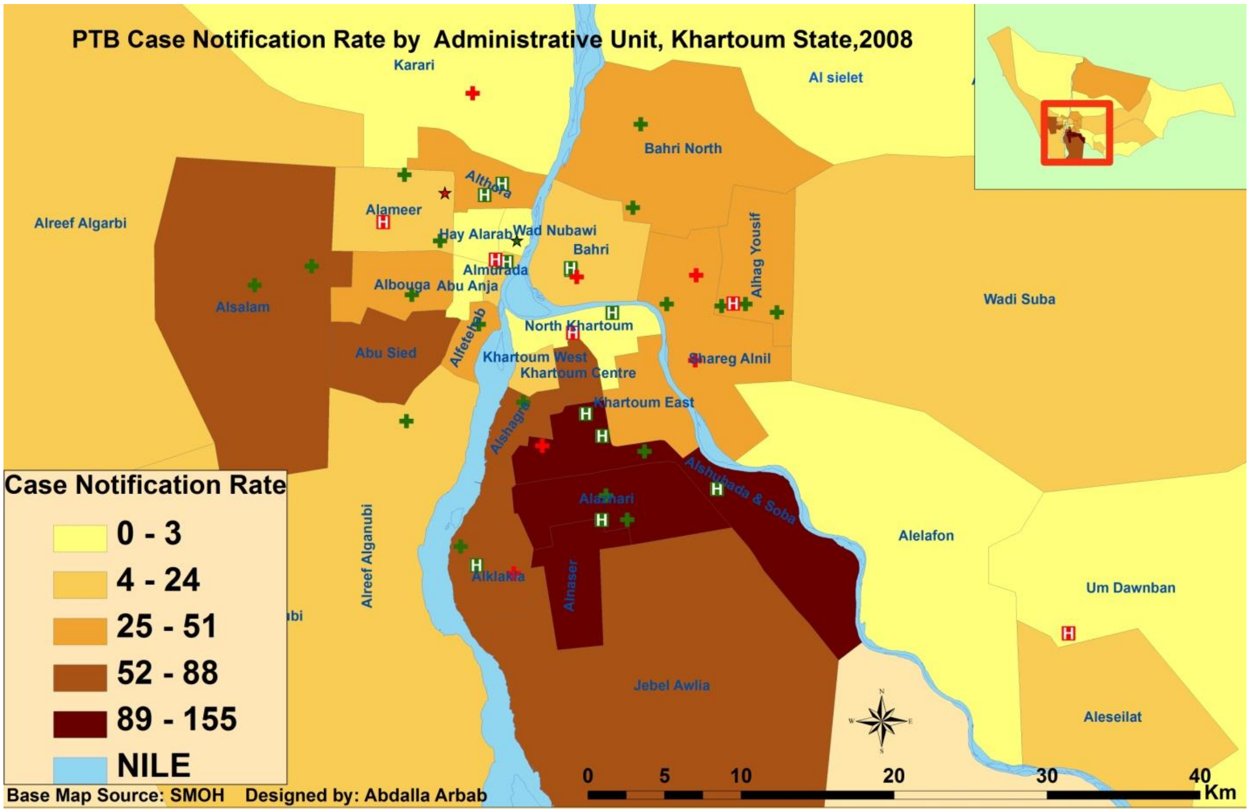
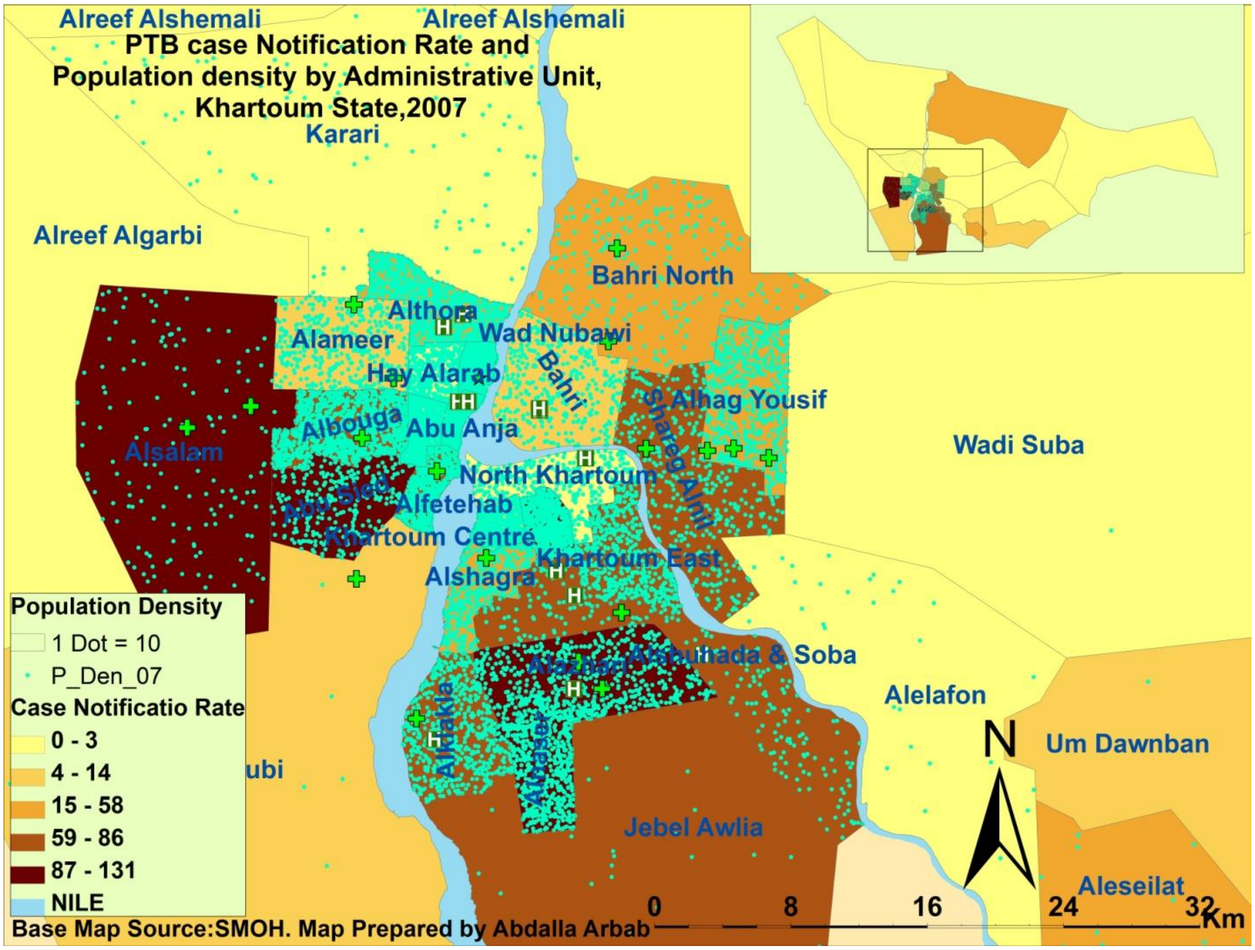


Figure 21 and 22 shows the PTB case notification rate in 2007 and 2008 and comparing the two maps we can see there was a shift in AUs with high TBCNR in 2007 to 2008. Alsalam AU reported high TBCNR in 2007 together with Abo seid, Al Azhari and Al Naser, however in 2008 the number of notified cases in Alsalam and Abo seid AUs reduced and remain the same in Al Azhari and AlNaser AU with shift of Alshouhada&Soba AU to AUs with high PTB notification rate.

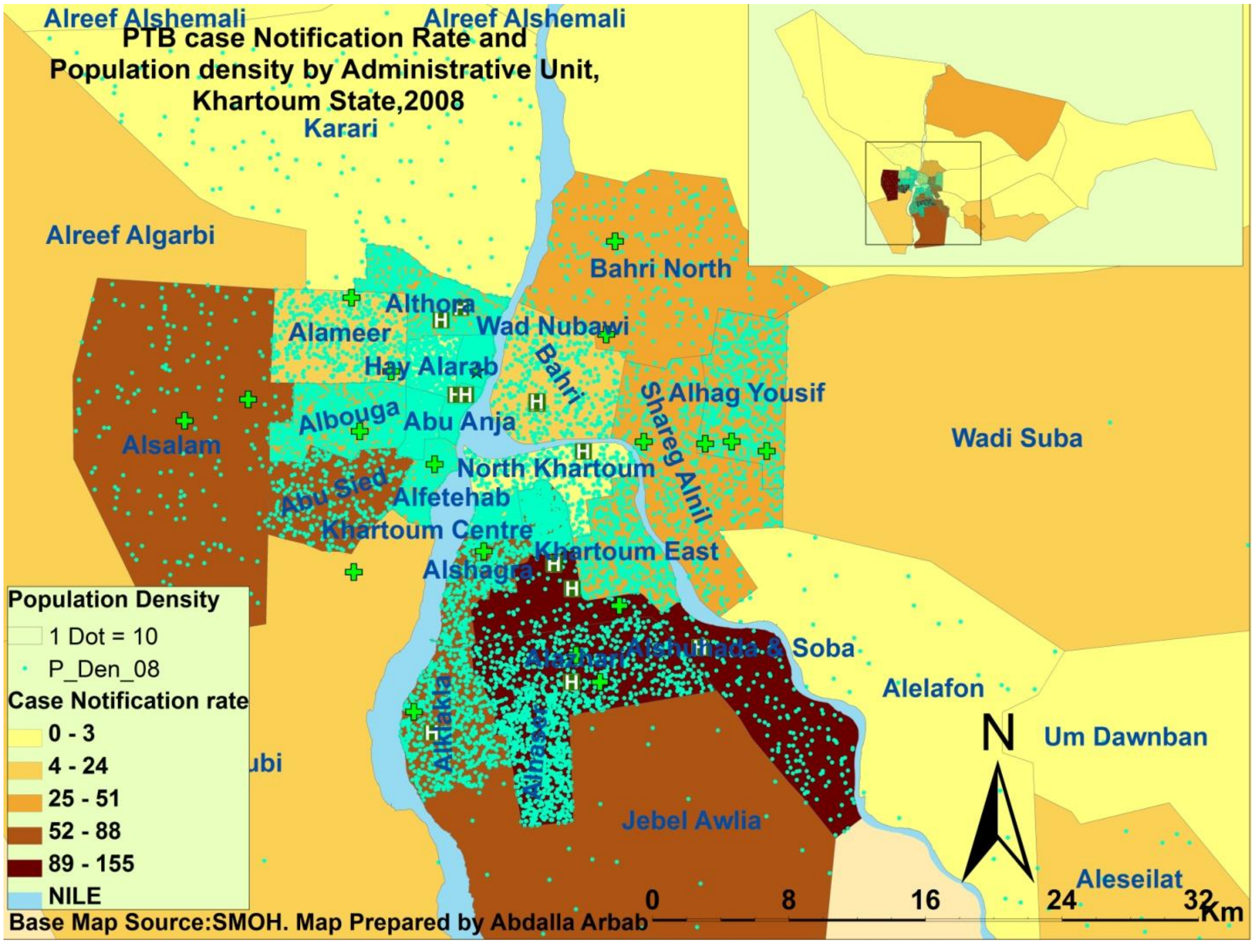
Figure 23: Shows PTB case notification rate and population density by Administrative Unit according to year 2007.



This figure shows the end result of overlaying population dot density map layer over the TBCNR layer as in figure 21. Here the tourmaline green dot represents population density, where single dot signify a population density of 10 units.

It is evident from these dot density map that not all densely populated areas were the one with high PTB intensity for example, Wad Nubawi, Hai Al Arab, Abu Anja, Al Shagara, Khartoum North AUs are the most densly populated areas but with very low PTB case notification rate. Three areas with high population density and high TBCNR are Al Azhari, Al Naser and Khartoum Center. However Asalam AU with high TBCNR but with low population density.

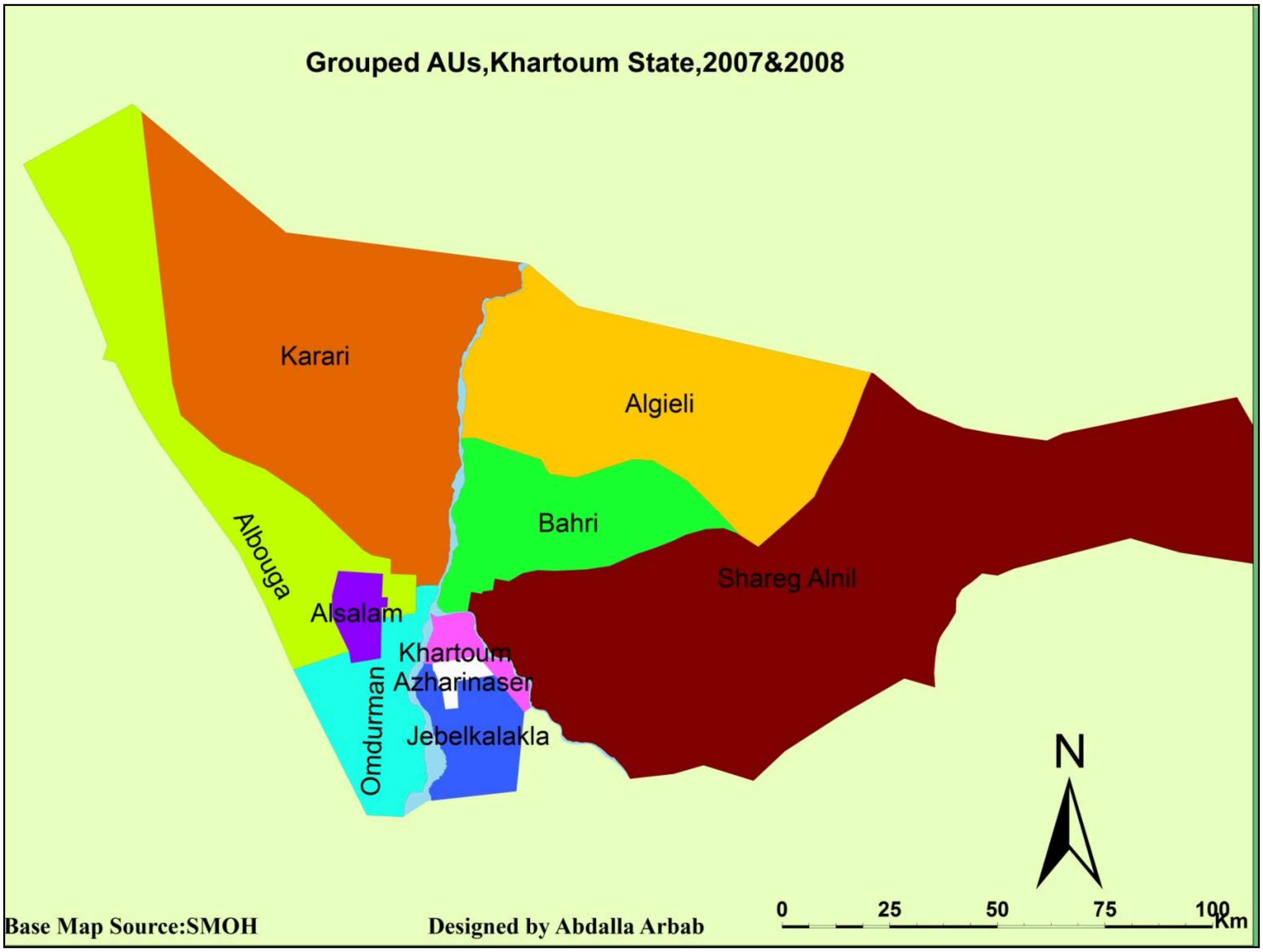
Figure 24: Shows PTB case notification rate and population density by AU according to year 2008



This figure is not significantly different from figure 20 but PTB intensity extents to a new AU, which is Al Shouhada&Soba.

For the sake of statistical analysis the 36 AUs were regrouped into 10 AUs by geo-processing the state map using dissolve tool in spatial data management in ArcTool box of ArcGIS 9.3

Figure 25: shows the Grouped AUs



This figure created by regrouping the 36 AUs according to TBCNR. For several areas the TBCNRs were low than 4; hence collapsed into larger areas.

Table 7: shows the category of PTB patients in the grouped 9AUs

Administrative Unit	Category of patient					Total
	New	Relapse	Transfer in	Treatment after default	Failure	
Jebelkalak	568	32	3	21	2	626
azharnaser	1124	24	10	49	0	1207
karari	187	5	5	5	0	202
Khartoum	820	16	11	31	1	879
Bahri	331	11	1	14	0	357
Omdurman	355	21	3	23	0	402
Shargelnil	511	39	20	35	0	605
albogaameer	740	46	8	19	0	813
Alsalam	668	36	34	23	0	761
Total	5304	230	95	220	3	5852

Table 8: shows distribution of total PTB cases by AU

Area	N(%)	New cases (n, %)	Retreatment cases (n,%)
Jabelkalak	**626(10.7)**	**568 (10,7)**	**58(10.6)**
azharnaser	**1207(20.6)**	**1124(21.2)**	**83(15.1)**
karari	**202(3.5)**	**187(3.5)**	**15(2.7)**
khartoum	**879(15)**	**820(15.5)**	**59(10.8)**
Bahri	**357(6.1)**	**331(6.2)**	**26(4.7)**
Omdurman	**402(6.9)**	**355(6.7)**	**47(8.6)**
Shargelnil	**605(10.3)**	**511(9.6)**	**94(17.2)**
Albogaameer	**813(13.9)**	**740(14)**	**73(13.3)**
Alsalam	**761(13)**	**668(12.6)**	**93(17)**
Total	**5852(100)**	**5304(100)**	**548(100)**

Pearson Chi-square = <0.001, which shows there is a significant difference between the proportion of new and re-treatment cases between the AUs.

Figure26: shows treatment outcome of reported PTB cases according 2007

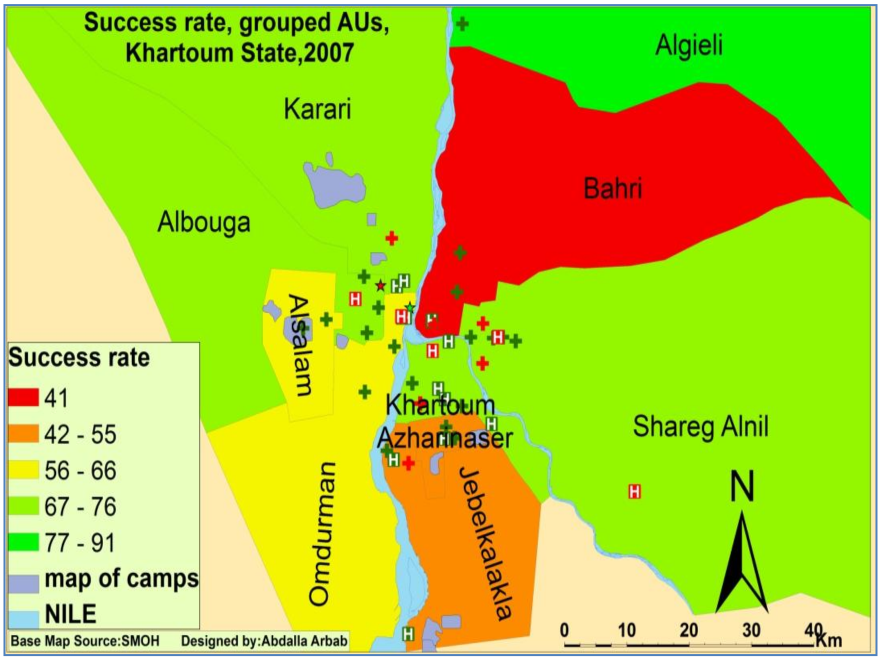
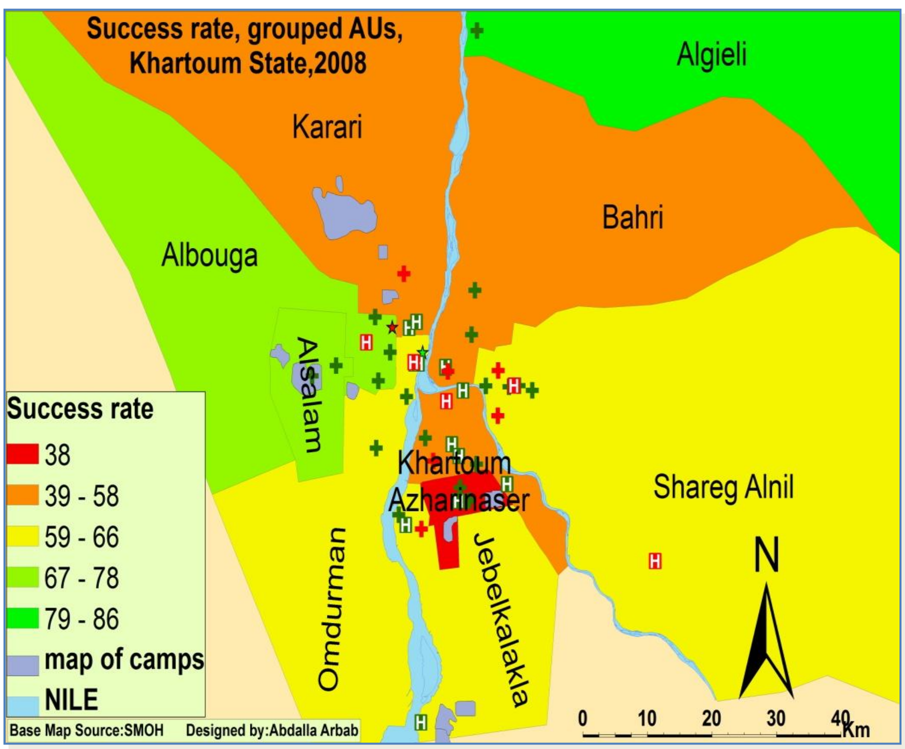
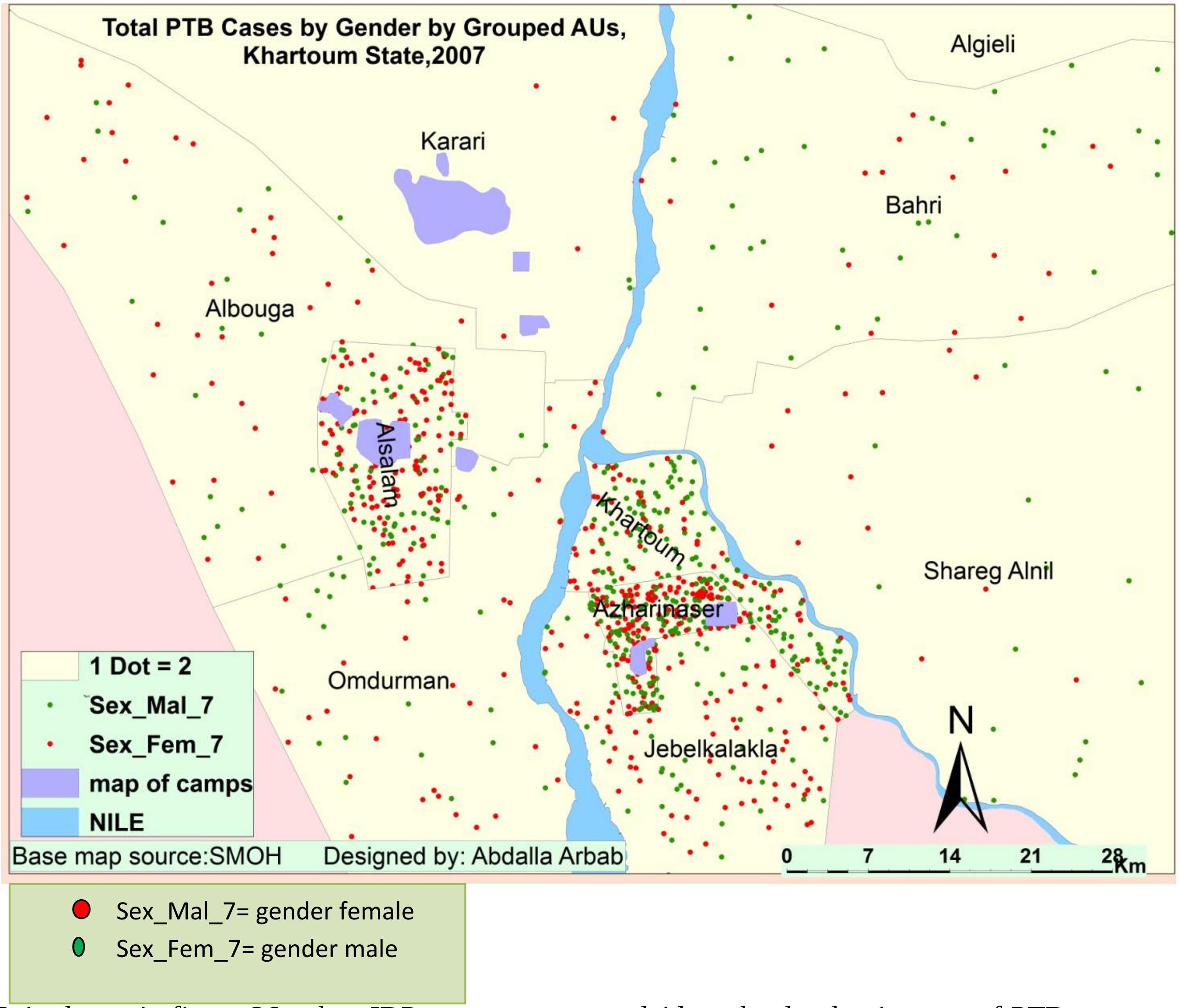


Figure27: shows treatment outcome of reported PTB cases according2008



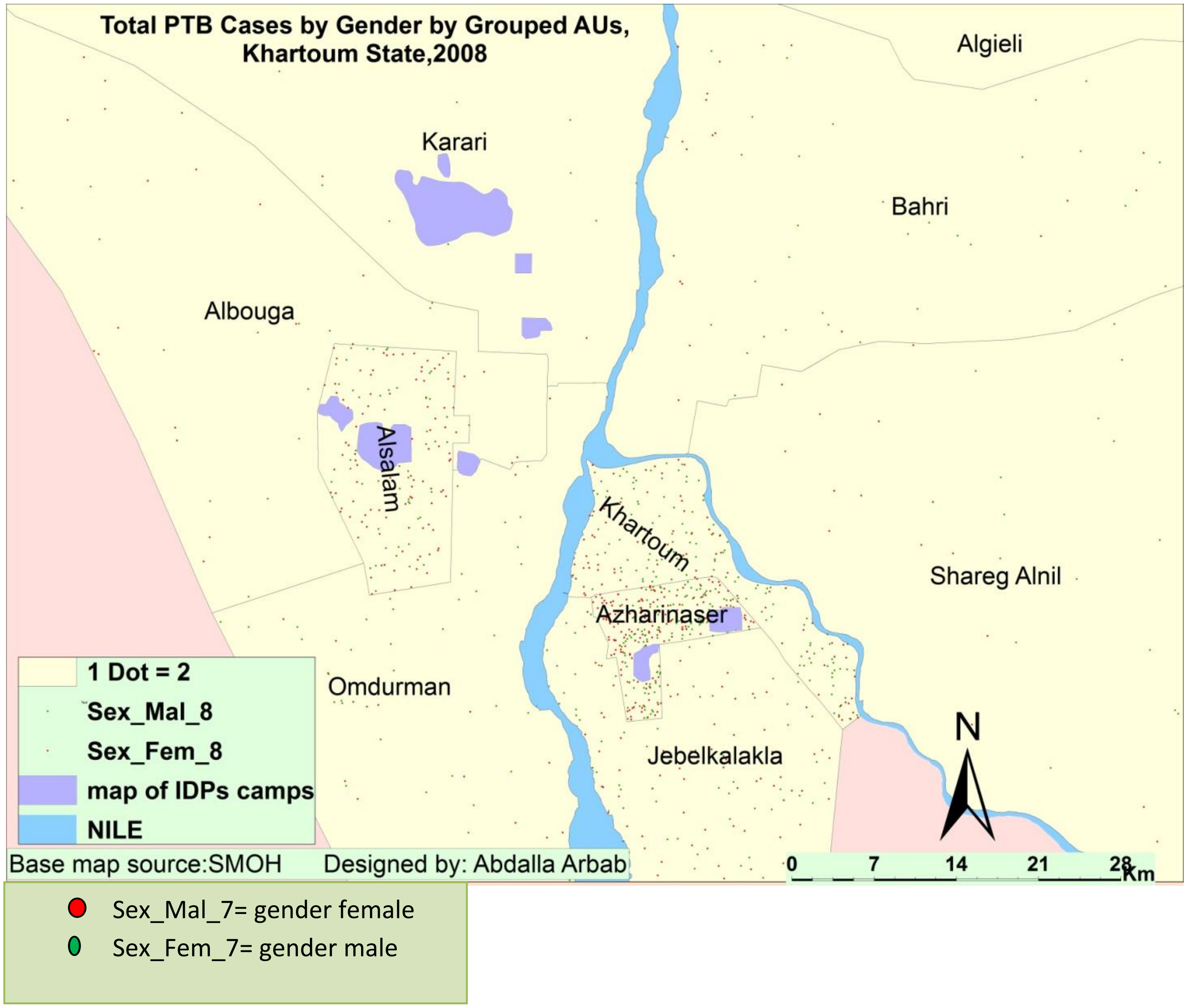
Pearson chi-square showed significant difference in the distribution of treatment outcome among the AUs in 2007 and 2008. P-value = <0.001.

Figure 28: shows dot density Map of PTB cases by gender, 2007, where each dot represent 2 cases for females (red dot) and for males (green dot)



It is shown in figure 26; when IDPs camps were overlaid on the dot density map of PTB cases, these IDPs areas fell in the areas with high PTB intensity. In Karari AU data were missing and if collected the picture will change to areas with high PTB intensity too.

Figure 29: shows dot density Map of PTB cases by gender, 2008



This figure represents the same picture as in 2007.

Figure 30: shows dot density Map of PTB cases by gender overlaid on population density layer for year 2007 together with TBMUs from where data collected.

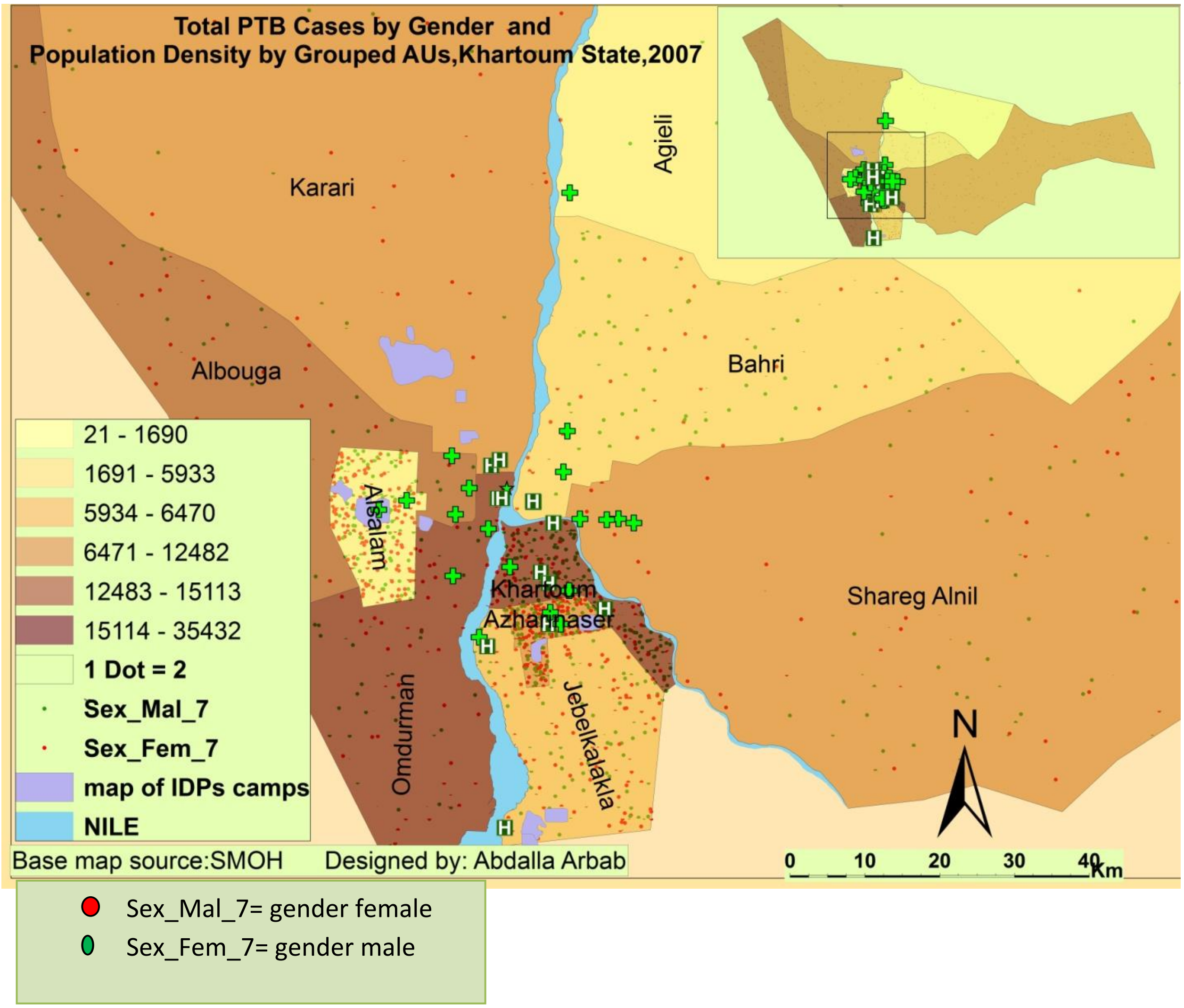


Figure 31: shows dot density Map of PTB cases by gender overlaid on population density layer for year 2008.

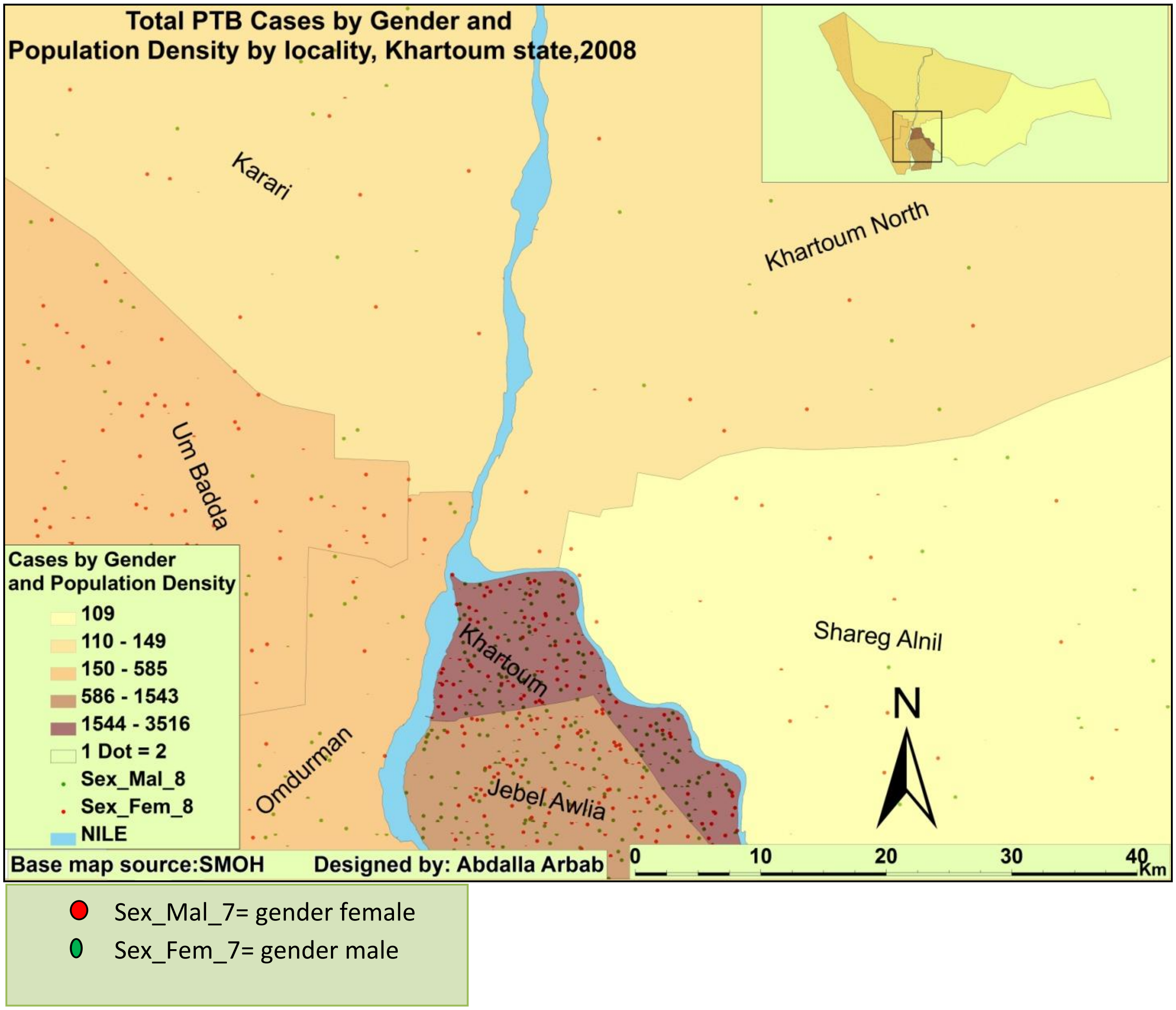


Figure 32: shows the rate of new TB cases notified in 2007 and 2008 by age group.

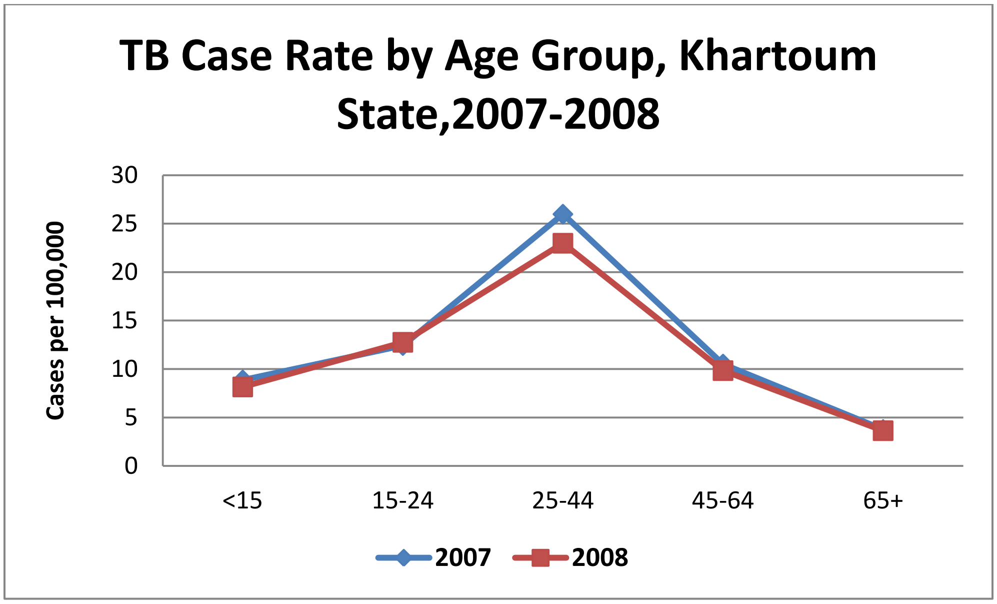


Figure 33: shows the rate of New TB cases notified in 2007 by age group and gender.

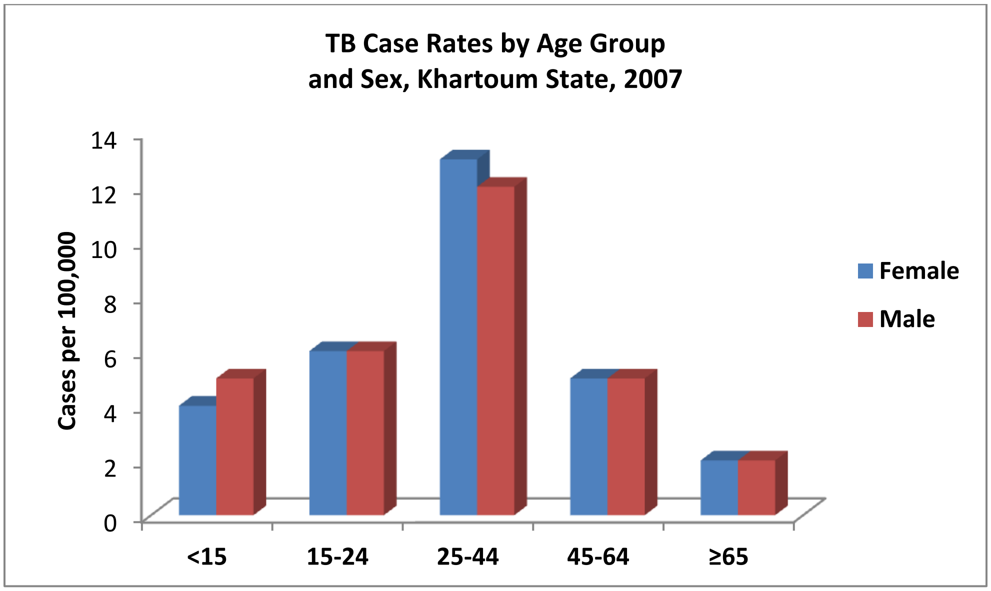


Figure 34: shows the rate of new TB cases notified in years 2008 by age group and gender

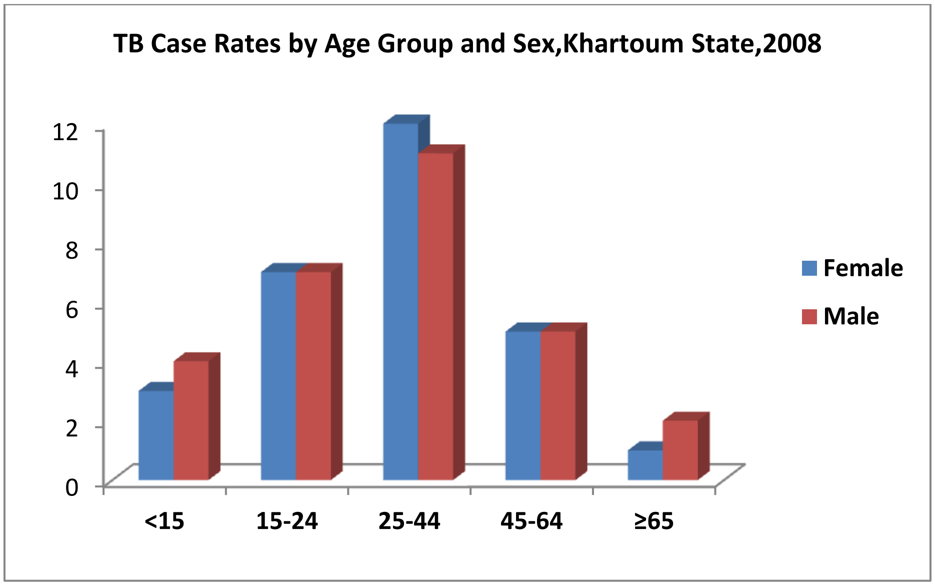


Figure 35: shows proportion of notified PTB cases by category by TBMUs according to year 2007, numbers in the below table represent the TBMUs.

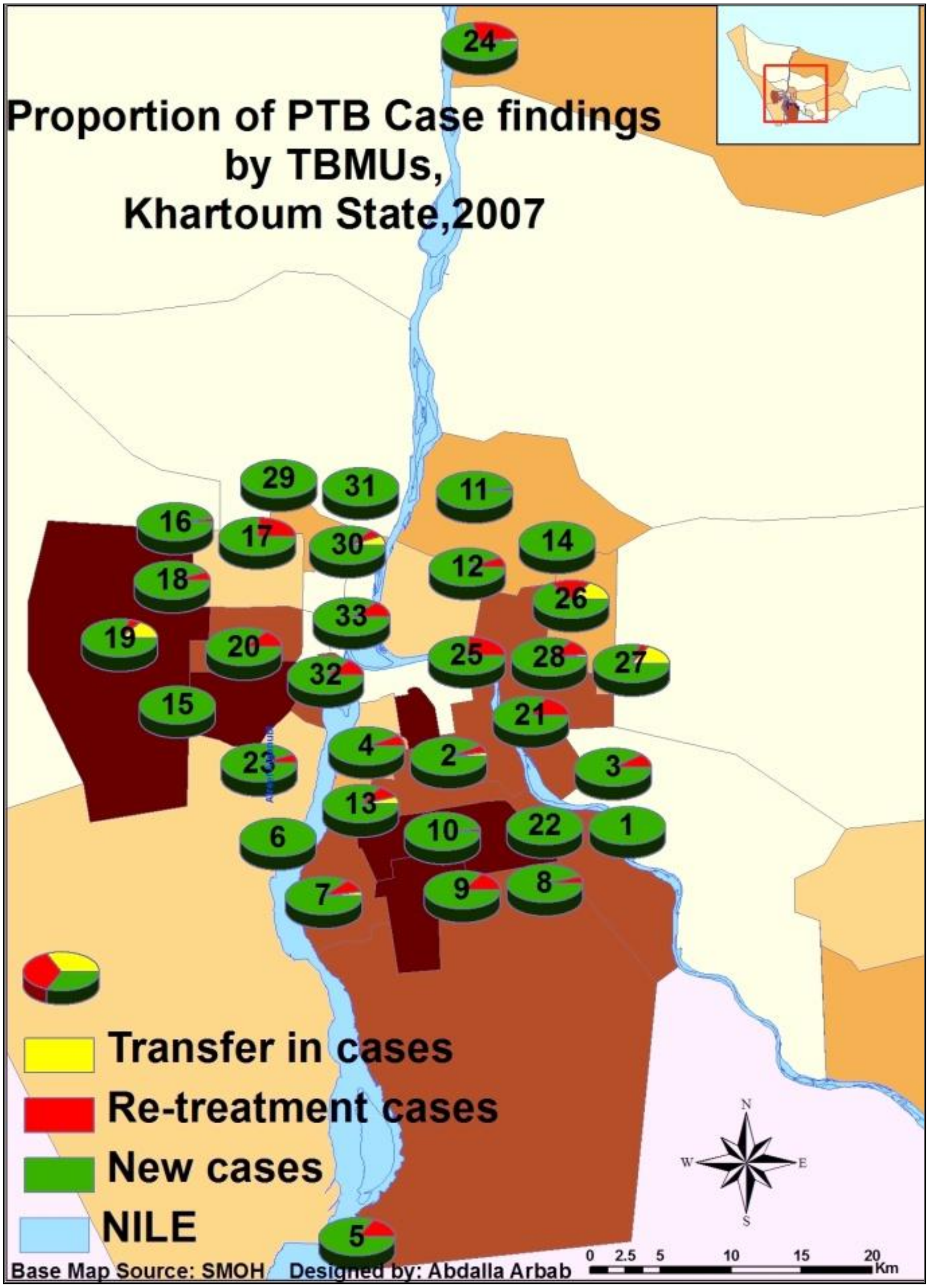


Table 10: shows TBMUS where data of case finding and treatment outcome illustrated by charts

1.W.Elgereif Health Center (HC)	2.Academia Hospital	3.Ibrahim Malik Hospital	4.Lamab HC	5.Jebelawlia Hospital	6.KlalaklaQubah HC	7.Turki Hospital	8.Bashir Hospital
9.Edhusen HC	10.Azhari22 HC	11.Droshab HC	12.Taybahahamdah HC	13.HKTC *	14.AhmedQasim Paediatric Hospital	15.OPH **	16.Rakha Hospital
17.Fitemab HC	18.Andalos HC	19.Salam44 HC	20.Manarah HC	21.Police Hospital	22.Soba Hospital	23.Salha HC	24.Gaili HC
25.Koko HC	26.Wehdaetihadi HC	27.Darsalam4 HC	28.Comboni HC	29.Bullok Paediatric Hospital	30.Naow Hospital	31.Abroaf HC	32.Aboseid HC
33.OTH****							

* Heart and Kidney Transplant center,** Omdurman Paediatric Hospital,***Omdurman Tropical Disease Hospital

Figure 36: shows proportion of notified PTB cases by category by TBMUs according to year 2008, numbers in the above table 10 represent the TBMUs.

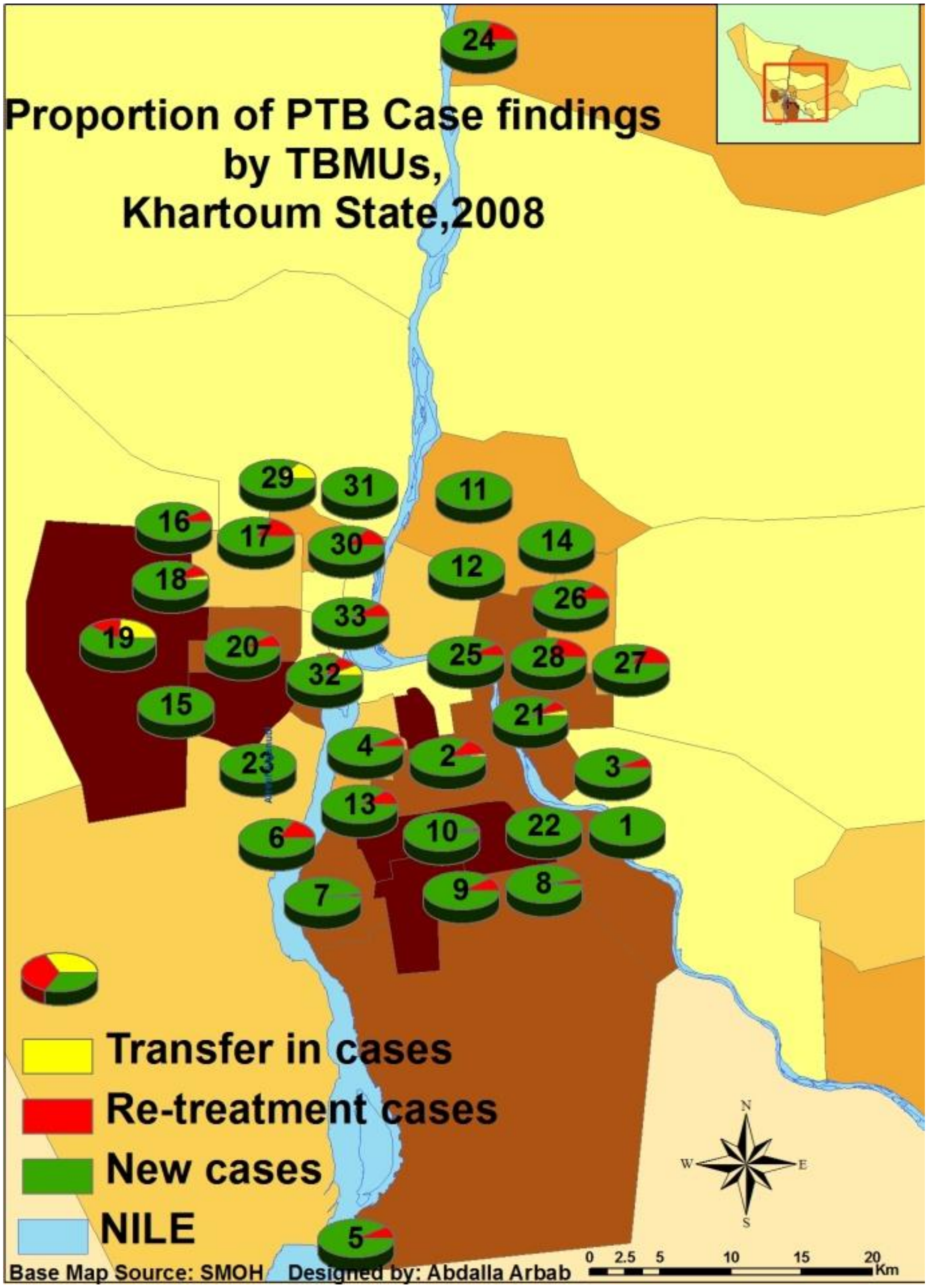


Figure 37: shows proportion of treatment outcome of the notified PTB cases during the year 2007. Numbers in the above table 10 represent the TBMUs.

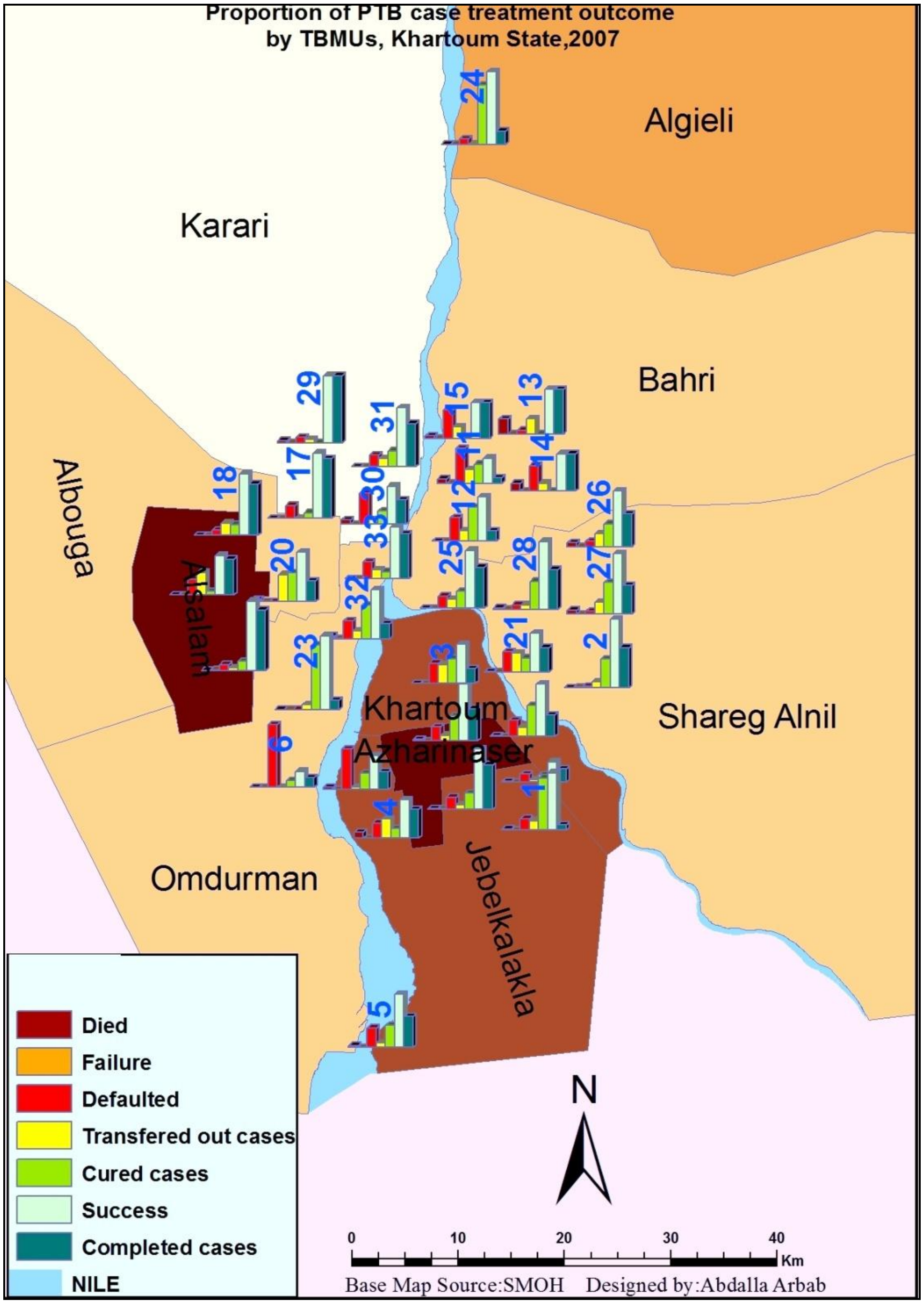


Figure 38: shows proportion of treatment outcome of the notified PTB cases during the year 2008. Numbers in the above table 10 represent the TBMUs.

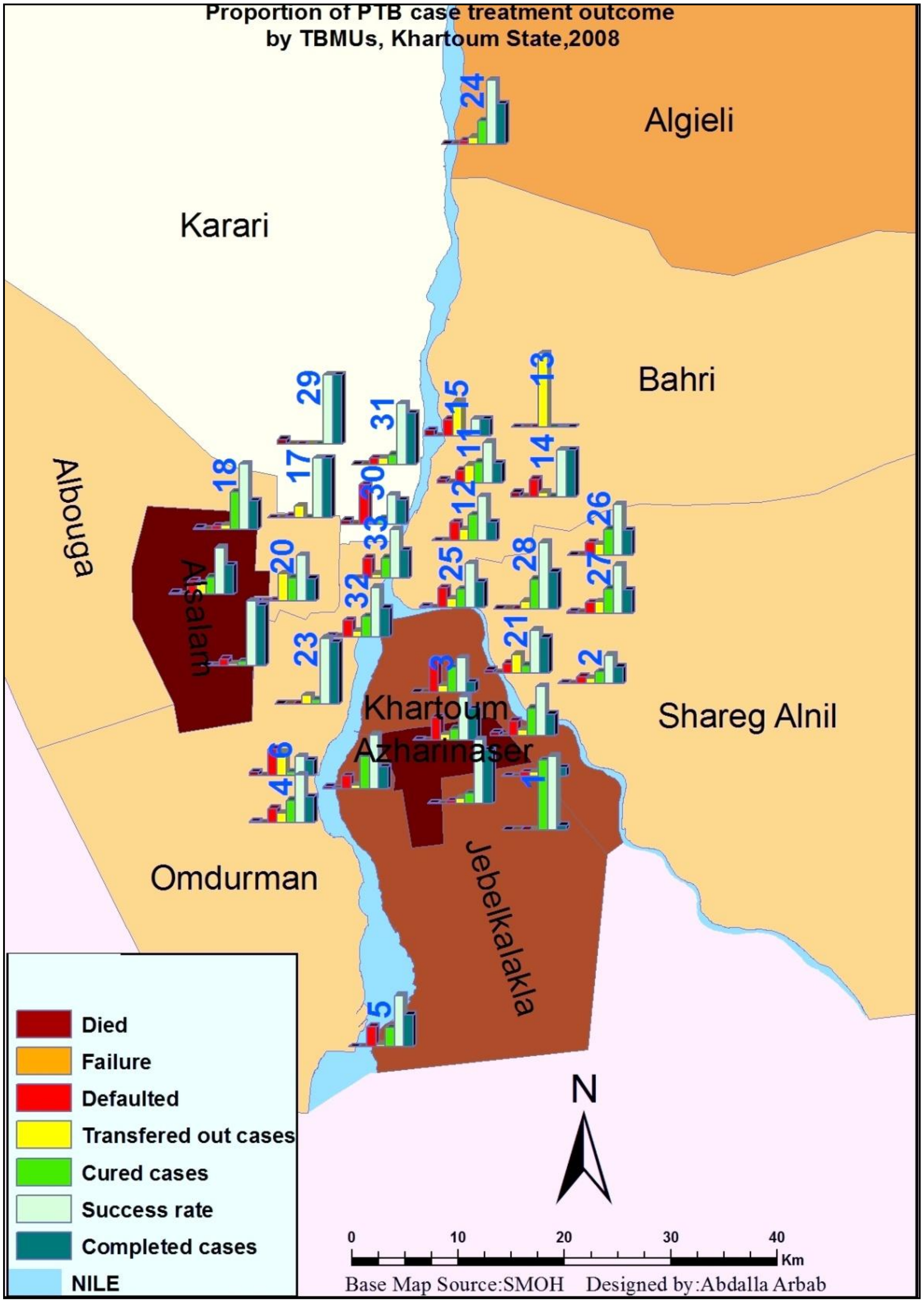
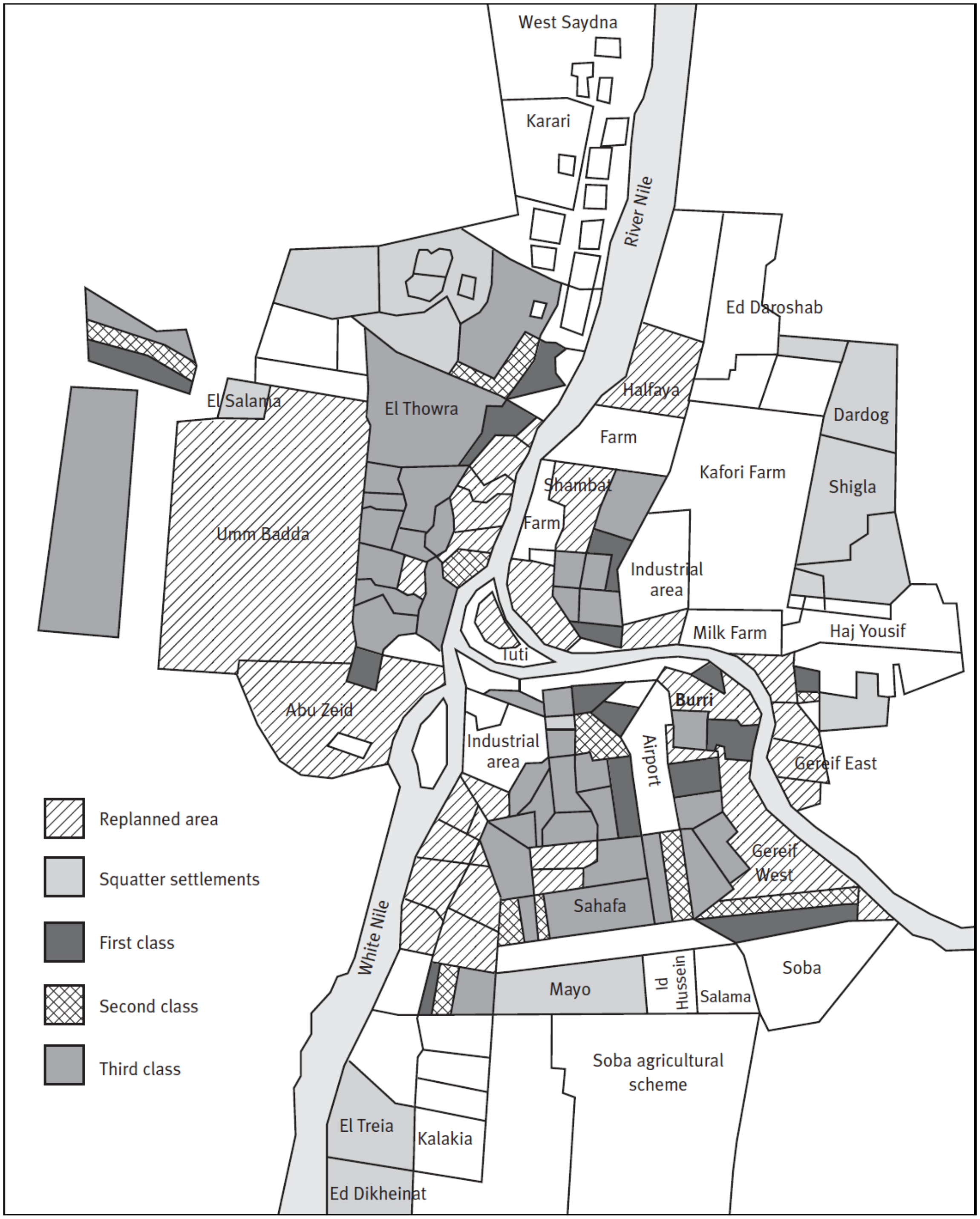
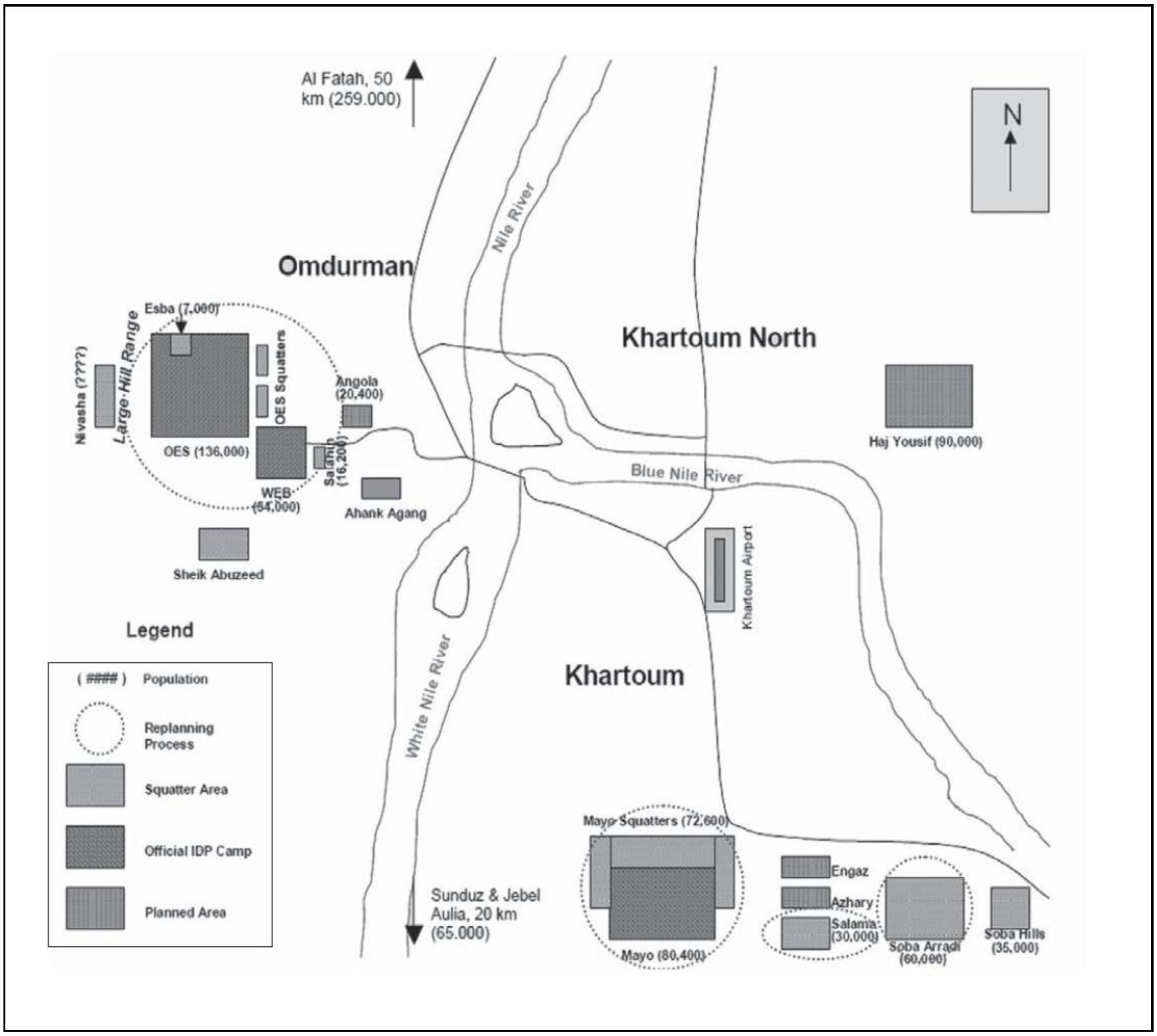


Figure 39: Shows map of Khartoum and classification of socioeconomic status by residential areas.



Source: HPG Commissioned Report, 2011, UK

Figure 40: shows the locations of IDPs camps in Khartoum State.



Source: Interagency Report, 2004

CHAPTER 6.DISCUSSION

The utility of GIS for research in health is manifold. We made the first attempt to systematically observe and illustrate the distribution of a highly prevalent chronic infectious disease; namely PTB during the research period 2010-2011. Altogether, 33 TBMUs and 36 AUs in Khartoum State were covered, where 6,182 PTB cases were available in the TBRs for our study years (2007-2008).

We found that distribution of PTB cases were attributable to several characteristics of the sociopolitical and socio-economical realities of Khartoum State. PTB cases were concentrated in AUs with areas of poverty, settlement areas of IDPs and areas of concentration of poor urban migrants.

Comparing our findings with available literature a number of studies have been conducted to answer research questions like ours by using comparable technological methods. Study using GIS have consistently showed that TB is common in low socioeconomic status population(14;15;20;21;24;37;40-42;45;66-68). However, many of the recent studies use a more advanced technique of GIS in performing advanced spatial scan statistics for a geo-referenced and geo-coded TB data and combining it with molecular epidemiology (DNA finger printing and RFLP) technologies to identify areas of TB transmission and incidence and to map areas of clusters/hotspots. One unpublished report which intended to find out the cause behind delay of TB diagnosis, where they used conventional method of comparing the delayed diagnosis with socioeconomic details available for individual data (69). They reported that as high as 80% of all TB cases in the study had a family monthly income of less than $100 and that less than 5% of the cases had incomes of more than $200 per month.

It is tempting to speculate that the high PTB case reporting may be associated with areas of low socioeconomic level, where IDPs population and urban slums are high also in our study since Khartoum state consists of socioeconomically heterogeneous administrative units.

Even though health service penetration appeared optimal throughout study areas, we found that not all TBMUs maintained data recording. Therefore it is plausible that our findings may have been influenced by the extent of information available for each AU. This aspect may be of particular relevance in the Northern area of Karari where areas of plausibly higher concentration of population and the population with low socio-economic living were missed from dataset due to unavailability of record at the facility.

When we look at the number of PTB cases by AUs in the two years, females dominated over males. This is in contradiction with contemporary reporting from other studies, where males outnumber females as regards the TBCNR and prevalence (69;70).This finding may owe to recent trends of TB epidemiology wherein more and more females seek treatment; many are active in outdoor activities like working in businesses which may increase the chances of further exposure to infectious sources outside the living areas. Interestingly, this may be an indirect evidence of increasing coverage of HIV screening and diagnosis. The higher prevalence of HIV among women may follow the common TB co-infection thus showing a proportionate rise in TB rates. Further evidence is necessary to ascertain this hypothesis. The age group 25-44 constituted the highest age group with PTB followed by age group 15-24, however Pearson chi-square showed no significant difference in the distribution of PTB between gender and between the age groups.

In Abu Anja, a densely populated area does not show proportionally high TBCNR. This may be explained by the data unavailability as is the case for Karari.

On the other hand, in Alsalam AU, where TBCNR appeared higher at 122, were not proportionally populated. It is impossible to explain this phenomenon from the available data; however this aberration may be clarified by household level data entries. We anticipate that the distribution of high TBCNR and population density may be spread in pocket areas in the AU. Further research may clarify this likely phenomenon.

The utility of GIS for health research depends critically on data quality(71). Therefore, the ability of GIS to detect disease clusters, associations between diseases, and risk factors like socioeconomic and environmental elements is hampered by the availability of quality data. GIS facilitates the performance of epidemiological research tasks far more quickly and with less effort, data quality, lack of spatial detail, and lack of spatial consistency between data sets reduces its utilization. Due to its ability to combine data from different sources, thus mapping diseases and factors related to their spread, GIS is nonetheless a suitable tool for disease surveillance, monitoring and evidence-based decision making.

The data used in this study is subject to GIS limitations, as it lacks the detailed information of patient location and information on socioeconomic status. Data collected for mapping PTB in

Khartoum state was based on the information available in the TBRs and TBTCs, where there was often no referenced address for patient location and where the only informative addresses describing patient residence location that could be used as a unit of analysis was the AU. Due to small numbers of cases in about 26 AUs, the 36 AUs were dissolved into 10 AUs, in order to be able to perform statistical analysis. This was a factor that could have compromised the micro level accuracy of our findings.

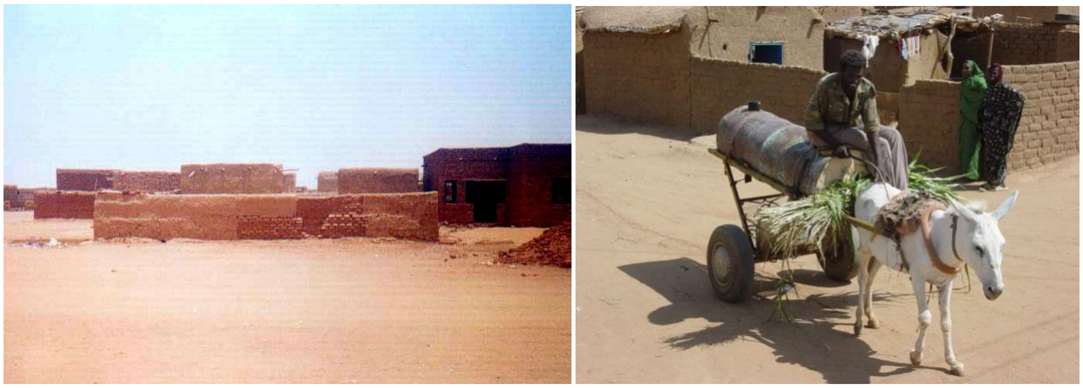
This study of PTB cases during two years constitutes a retrospective study of geographical distribution of PTB in Khartoum State using ArcMap and ArcTool box of GIS in symbolizing and mapping the proportion of notified new PTB and all (new + re-treatment) PTB cases, with the intention of examining the intensity and geographical distribution of PTB cases, determining whether there were significant differences in spatial distribution among the 36 AUs of Khartoum State, and identifying associations between high proportion of PTB and socio-demographic and socioeconomic factors in these areas of high PTB. Despite missing data from 13 of the 46 TBMUs, we were able to map the geographic distribution of PTB in Khartoum State by using the Symbology tab of ArcMap to create a variety of thematic maps to represent the average distribution rate of PTB in the state for two years at the locality, AU, and newly grouped AU levels. In addition to that, drawing pie and column charts to represent PTB case findings and treatment outcome at the TBMU level was done to communicate our understanding with other audiences. Through the use of choropleth and dot density maps for representation of PTB, it was clear that there were specific AUs in which the intensity of TB cases was high in reference to population density and poor socio-economic status during these two years. The significant association of population density (crowding) and poor socio-economic status in facilitating the transmission of PTB has been documented using proxy indicators due to the lack of socioeconomic indicators in census data at the level of AUs and difficulties in conducting survey due to time and cost consideration.

Below are Google images from eye altitude of 3013 *ft* which allows us to visualize the pattern of buildings in the residential areas of AUs with higher PTB notification. This gives an overview of unplanned urban settlements in the Al Azhari AU at a best resolution in an understandable manner. These buildings look unplanned, irregular, and squatter and made up of mud as depicted in the picture below (figure 42). However, the same resolution in another area shows the larger concrete and brick constructions with apparently more planned urban settlement including views of greenery and motor vehicles. This gives a picture of socioeconomic differences in the two areas. Google Earth thus provides proxy indicators that differentiate socioeconomic strata of people living in different areas (figures 41-50) and additionally when compared with fig. 39 and 40, where shown areas of different social classes and distribution of IDPs in Khartoum State confirm that areas with high TBCNR are areas of most deprived and poor population. These exemplify the differences observed from distant and closer views respectively. This justifies the usefulness of these imaging technologies in illustrating the gap in the living standards of people by areas of settlement.

Figure 41: Alazhari(low socioeconomic area)

View Location: 15°28'18.24'' N 32°32'20.42'' E, July2009

Figure 42: Closer view of building patterns in the same Al Azhari AU: (low socioeconomic area)



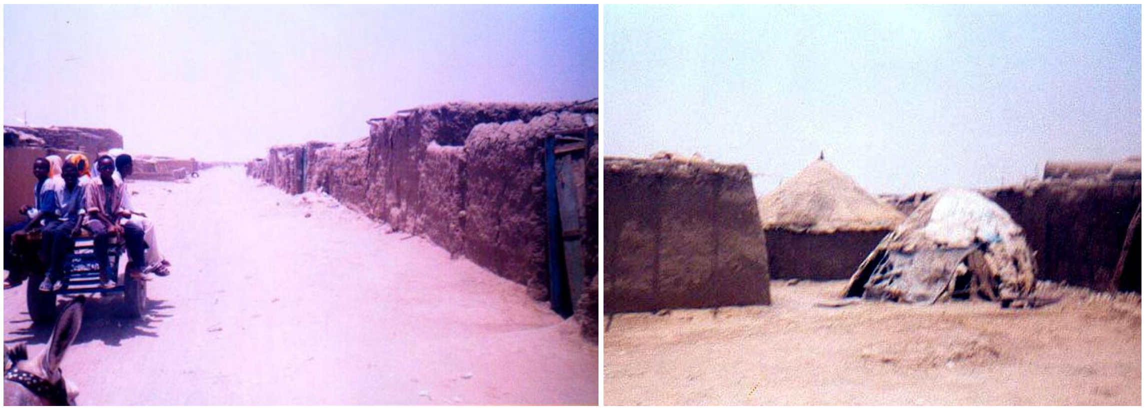
Source: Dr.Eltayeb G,The Case of KRT,2003 **Source:UN-Habitat,2000, water vendor**

Figure 43: Alnasr AU(low socioeconomic area)

VView Location: 15°27'58.01" N 32°32'24.36" E September 2011

Fig. 43 shows Al Nasr AU, one of the AUs that have high PTB intensity; it is an area of IDPs camps and urban slums with same pattern of building. Photos in Figure (44) from the same area give a view of material used in the buildings (mud and cardboard), the mean of transport and absence of cars and green coverage. Similarly, when compared with images in figures 45, 46 49&50 of first and second class areas with different building pattern, we can observe the presence of green coverage, cars in the streets and around the houses and material used in buildings (concrete and bricks).

Figure 44: View of building patterns in Mayo area Alnasr AU: (low socioeconomic area)



Source:Dr Galaleldin E:The case of Khartoum,2003

Figure 45: Alamarat (first class areas high socioeconomic area)

View Location: 15°34'00.10" N 32°32'52.08", E Septmber2011

Figure 46: Arkweet (first and second class area, high socioeconomic area)

View Location: 15°32'29.27" N 32°34'23.64" E, August2007

Figure 47: Alsalam (low socioeconomic area)

View Location: 15°37'40.36" N 32°19'36.68" E, August2007

The complicated history of camps and irregular sites in Khartoum is often reflected in the names given to these locations by the people who live there. One example is Al Salam Camp in Al

Salam AU, which is referred to as '*Jaborona*', meaning 'we were forced' (72). These pejorative names by itself express how poor and deprived those communities are.

The above image from the area of '*Jabarona'*, now Alsalam AU is one of the AUs with high PTB case load. Again, when looking the building patterns are like other poor areas, no green coverage, no cars and means of transport to the majority are cart pulled by donkey and photo in figure 48 gives a closer view of buildings pattern and nature of these area. Compare this area with other areas of first and second class in figures 45, 46 49&50 again one can see the difference of socioeconomic status between these areas using the same above description.

Figure 48: View of building pattern and transport used in Asalam AU (low socioeconomic area)

Source:Dr Galaleldin E:The case of Khartoum,2003

Figure 49: El Ryadh(first class areas high socioeconomic area)

View Location: 15°34'21.82" N 32°33'58.56" E, August2007

Figure 50: Wad Nubawi(first class areas high socioeconomic area)

View Location: 15°39'28.78" N 32°29'32.67" E, August2007

In addition to thematic maps, pie and bar charts representing TBMUs and PTB cases findings and treatment outcome indicators were produced to enable visualization and communication of understandings with audiences (figure 35-38).

6.1 Limitations:

Given the retrospective nature of this study we were limited to use only the addresses recorded in the TBRs and TBTCs. These addresses are incomplete and lack geographic coordinates of the exact location of the patient's house. This study was limited to perform only thematic maps to show the areas of high intensity TB cases and compared it with population density. Due to incomplete residential addresses, the application of spatial analysis to identify the geographic point distribution and spatial patterns of TB cases in Khartoum State was not possible to perform.

Lack of socioeconomic and environmental data at the mapping level was an additional limitation of this study. Lack of molecular epidemiology (IS6110 RFLP) data of the MTB strains of reported PTB cases, which can be combined to spatial mapping of TB cases to determine TB transmission was another limitation of this study. But clearly, it would require a separate methodology and would be resource intensive study of this kind. GIS enables complex analytical data processing beyond simple disease distribution and association with explanatory factors. We reckon that future analysis could be done by using GIS but we were constrained by the limitation of important background variables, like exact GPS coordinates of the exact residence of the PTB patients missing from data sets. These are the gaps to be filled by future endeavours.

6.2 Strengths of the study:

One of the strengths of this study is the proposal of using innovative ways to overcome limited availability of socioeconomic data by using proxy indicators like Google maps of areas with high incidence PTB.

Strength is that this is the first study to be conducted in the country in geographic mapping of PTB using GIS. Therefore, it showed the difficulties and constraints that need to be considered by any further study to be conducted in disease mapping both in general and with specific regard to TB. This study also paved the way for future research utilizing GIS to detect TB transmission pathways in a larger level than at individual levels.

6.3 Conclusion:

Understanding the geographic distribution of PTB and identifying areas with high TB case intensity and factors contributing to high occurrence of PTB in specific areas will allow better planning of interventions and disease monitoring and control in areas with high TB incidence. We found that the distribution of PTB in Khartoum State attributable to several characteristics of sociopolitical and socio-economical realities of Khartoum State. PTB was observed to be concentrated in most poor deprived AUs of the state. In countries with limited resources and poor quality of TB patient data, data on socioeconomic and environmental factors, specifically, can be obtained from Google maps by analyzing the pattern of buildings, the materials used in building, green coverage, and availability of cars around the houses.

6.4 Implications:

Since research using GIS depends on quality data, and especially data on residential and no-residential locations, prospective studies are recommended to give the chance to collect detailed information concerning TB cases in regard to residential address and non-residential address since many studies found that TB transmission occurs outside the residential places and is clustered around areas of social gathering like local bars (Shebeens), schools, clinics and churches.

Emerging use of technological tools has been successful in understanding the dynamic pathways of TB transmission. The similar tools of which GIS is an example makes it possible to implement strategies for public heath intervention in infectious disease-prone area; but not limited to developing country settings.

GIS technology can also be useful in estimating trends of disease epidemiology over time. The same GIS systems may be of paramount importance in identifying the spread of newly emerging epidemics including HIV infection and non-infectious disease like diabetes Mellitus (DM).

In the context of high TB prevalence regions like Sudan, GIS can be instrumental as informant for policy settings and decision making. Hence we recommend that a central electronic database be created whereby the disease distribution and trends are easily at hand. Integrating such information technological tools in the national health information systems, will strengthen the efficacy of national and regional programmes like NTP programme.

6.5 *Future research:*

Future research that takes into consideration all the difficulties and constrains faced during this studies is recommended.

- Research that targets identifying the geographic point distribution and spatial patterns
- TB transmission pattern and clustering
- Triangulating molecular epidemiology to geographic mapping of TB
- TB risk and socioeconomic level
- Extend the technology in studying epidemiology of other communicable and non communicable diseaes.

Annexe 1: TB Register

وزارة الصحة الاتحادية

المشروع القومي لمكافحة الدرن

سجل مريض الدرن

TB Register Book

Serial Number رقم المتسلسل	Date of registration تاريخ التسجيل	TBMU اسم المركز التشخيصي	Name الأسم	MF ذكر – أنثي Sex النوع	Age العمر	Refer by حول بواسطة	Address العنوان	Symptoms*** الأعراض	Date symptoms تاريخ الأعراض	Treat Facility المركز المعالج	Treatment supporter مراقب العلاج	DOT Daily yes/No	Date of Treatment تاريخ بداية	Treatment category نوع العلاج **	Site P/EP	*Type of patients أنواع المرضي،					
																N	R	F	D	T	O

*N= جديد R= نكسه F= فشل D = انقطاع T= محول O=أخري cat 1 --- cat 11 نوع العلاج **

Annex 1 continued

سجل مريض الدرن   Year………السنة   **TB Register Book**

Results of sputum smear microscopy and other examination												Treatment out-come & date نتائج العلاج & التاريخ						TB/HIV activities حالات مرضي الإيدز				
Before treatment قبل بداية العلاج				2 month الشهر الثاني		3 month الشهر الثالث		5 month الشهر الخامس		End of treatment الشهر الثامن		Treatment out-come نتائج العلاج								يستخدم العازل الذكري Condoms use		
Sputum smear microscopy result	Date /lab. No	HIV result[3] date تاريخ نتيجة فحص	X-Ray result	Sputum smear microscopy result	Date /lab. No التاريخ /رقم المعمل	Sputum smear microscopy result	Date /lab. No	Sputum smear microscopy result	Date /lab. No	Sputum smear microscopy result	Date /lab. No	Cure شفاء	Complete إكمال	Failure فشل	Died توفي	Default انقطاع	Transfer محول	ART Y/N	CPT Y/N	Yes	No	Remarks ملاحظات

*****نتائج الاشعه : موجبه -- -سالبه – لم يفحص

Annex 2: TB Treatment Card

Name:------------------------------- ---الاسم
Sex (النوع) M (ذكر) F (أنثى) Date of registration:-- ---------------- ----تاريخ التسجيل
Age:-------------العمر Health facility----------------------------الوحدة الصحية
Address:-------------------- ---- --العنوان كامل
Name /address of community treatment supporter (if applicable)-----------------------
Name and address of contact person-----------------------------أسم وعنوان اقرب الاقربيب
1-**INITIAL PHASE(الفترة الأولي المكثفة)** prescribed regimen and dosages **Referral by :**

CAT(11) المجموعة الثانية

·Self-referral	محول من تلقاء نفسه
·Community member	محول من عناصر المجتمع
·Public facility	محول من وحدة صحية حكومية
·Private facility /provider	محول من عيادة خاصة
·VCT/ART facility طوعى/علاجى للايدز	محول من مركزفحص

S(E)	RH	Z
إستربتومايسين	ريفانبا	بيرازيناميد

S	RH	Z	E	Co-trimoxazole العلاج الوقائي الكيميائي للايدز	ART علاج مضاد فيروس الإيدز	Condoms عوازل		Other أخري
						Yes	No	
إستربتومايسين	ريفانبا	بيرازيناميد	إيثامبيتول					

· Pulmonary رئوى·Extra pulmonary خارج الرئة. Specify (حدد)-----------------
Type of patient(check one)

·New جديد · Treatment after defaultعودة علاج بعد انقطاع
·Relapse نكسة · Treatment after failure علاج بعد فشل
·Transfer in تحويل · Other, specify ------------حدد) أخرى

Sputum smear microscopy	Weight(kg) الوزن		
Month الشهر	Date التاريخ	Lab No. رقم سجل المعمل	Result النتيجة
0			
2			
3			
5			
8			

TB/HIV مريض الدرن مصاب بالإيدز

	Date التاريخ	Result*/ Amountالنتيجة/ الكمية
HIV counseling الارشاد النفسى		
HIV testing فحص الإيدز		
CPT start العلاج الوقائي للايدز		
ART start العلاج الفيروسي للايدز		

***(pos)**Positive(موجب)(**Neg.**)Negative(سالب)(**1**)Indeterminate(غير محدد),(**ND**) **Not Done/unknown(لم يتم أو غير معروف),(**R**)Refuse(رفض) (**: means give remarks)

Annex 3: National Endorsement

National Ministry of Health

General Directorate of Planning
Policy & Research

Directorate of Health Economic
Research & Information

Research Section

وزارة الصحة القومية

الإدارة العامة للتخطيط والسياسات والبحوث

إدارة اقتصاديات الصحة والبحوث والمعلومات

قسم البحوث الصحية

Date: 10/10 / 2010

No./Nmoh/rd/tc/ne/2/010

NATIONAL ENDORSEMENT

This is to certify that the Federal Ministry of Health is accepting the request of ***Dr. Abdalla Ibrahim Arbab Mohamed salih*** from ***NATIONAL Tuberculosis Control Program, National Ministry of Health Sudan,*** to undertake the study entitled ***(Mapping Pulmonary Tuberculosis in Khartoum state using Geographic Systems (GIS))*** to be carried in Sudan.

N.B: **The PI should submit the full study proposal for the Ethical review.**

Dr. Iman Abdalla Mustafa

Director, Directorate of Research

السودان. الخرطوم. وزارة الصحة الاتحادية. تقاطع شارع عثمان دقنة مع شارع النيل. الرمز البريدي: 11111. ص.ب 303

E-mail : fmohresearch@yahoo.com

Annex 4: Ethical Approval Letter

Republic of Sudan
National Ministry of Health

HEALTH RESEARCH COUNCIL

NATIONAL RESEARCH ETHICS REVIEW COMMITTEE

Date: 24/11 / 2010

This is to certify that the proposal ***(No. 139-11-10)*** *entitled* ***(Mapping Pulmonary Tuberculosis in Khartoum state using Geographic Information System (GIS)*** *introduced by:* ***Dr. Abdalla Ibrahim Arbab Mohamed Salih*** *from* ***Institute of Health and Society, Section of International Community Health, University of Oslo****, has been approved by the* ***National Health Research Ethics Committee, National Ministry of Health*** ***to be carried out in the Sudan.***

The principal investigator is requested to submit a copy of the final report to the National Health Research Ethics Committee.

Federal Ministry of Health
Directorate of Research

Dr. Iman Abdalla Mustafa
Reporter of the
National Research Ethics Review Committee

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